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THE BOTANY OF CACAO.

ONE of the main difficulties in the study of tropical crops is the scattered nature of the literature dealing with them, and particularly, perhaps, is this the case with the botanical literature. Standard text-books appear from time to time which deal with every aspect of a single crop, including the preparation and marketing of the product. In such works, however, the space devoted to the botany of the crop plant itself is necessarily reduced, and as a rule quite inadequate from the point of view of the student of crop improvement.

Botanical research on cacao, financed jointly by the British cacao-producing Colonies and leading cocoa and chocolate manufacturers, commenced at the Imperial College of Tropical Agriculture towards the close of 1930, and will no doubt be watched with interest by its indirect as well as by its direct contributors.

As an introduction to the research work, the Professor of Botany in the College has prepared a critical review* of the state of knowledge at its commencement, which is intended to serve both as a compact record of the subject and as an explanation of the lines of investigation which are being followed.

This takes the form of a descriptive article on the botanical relationships of *Theobroma Cacao*, the varieties which go to make up the species, its occurrence in the wild state, and its life-history and structure as a plant. The descriptive portion is followed by a discussion of those economic problems of the crop which are the special concern of the botanical investigator—the connection between yield and the constitution of the trees, the problems of selection of planting material, the problems of propagation, and the influence of environment. Quality is also touched upon, and a distinction drawn between intrinsic quality and quality as a result of uniformity.

A bibliography of seventy-five entries is appended, to which frequent reference is made throughout the text, and though this may not be absolutely complete it is hoped that no relevant information of major importance has been omitted.

* Published with this issue of *Tropical Agriculture* as a Supplement under the title of "The Economic Botany of Cacao", by E. E. Cheesman. Copies of this Supplement (Price One Shilling) can be obtained from the Editor, *Tropical Agriculture*, Imperial College of Tropical Agriculture, Trinidad, B.W.I.

In this manner an attempt has been made to produce a pamphlet of equal value to the botanical officer, who will want to turn to many of the original papers for amplification of details, and to the practical cacao planter who desires to follow with understanding the programmes of scientific officers working in his interest.

The publication has a secondary interest in that it illustrates the role of the botanist in horticultural and agricultural research. Modern applied botany is a subject not altogether understood by the layman, and is apt to be regarded as a somewhat unpractical sideline in agriculture. The manifold contacts of the science with practical considerations, in the case of the cacao crop, are here revealed.

GRAPEFRUIT PRODUCTION.

It is always difficult to forecast the future prospects of an agricultural industry because there are so many conditions which can arise which may upset the most careful estimates. A statement of the broader facts may, however, help to throw some light on the situation with regard to the grapefruit industry as it exists to-day.

According to recent information* it appears that world production of grapefruit is maintaining its upward trend. Larger crops are expected in all producing countries amongst which are included the United States, Porto Rico, Isle of Pines, South Africa, Palestine, the West Indies, Brazil and the Argentine. The bearing acreages in the chief areas where the fruit is grown are, in particular, likely to increase, as will be seen from the figures below :—

	Total acreage under grapefruit.	*Bearing acreage.* (1931)
Florida ..	93,000	31,000
Texas ..	70,000	14,000
Arizona ..	14,000	4,160
California ..	12,000	9,000
Porto Rico ..	8,310	6,120

In Florida, which is the most important grapefruit producing area in the world, the 1930-31 crop was the largest on record amounting to just over 11 million boxes. The 1931-32 crop is, however, estimated only at 8½ million boxes. There has been a phenomenal expansion in Texas where production has increased from 4,000 boxes in 1921-22 to 906,000 boxes in 1930-31. In the United States increase in production during the last ten years has been estimated at an average of nearly 6 per cent. per year.

The United States and Porto Rico have so far been the chief exporters of grapefruit, but more recently they have had to compete with South Africa, the West Indies, Palestine, Brazil and Argentine. The United Kingdom has increased its imports of grapefruit from countries other than the United States and Porto Rico, from 93,000 boxes in 1926 to over 200,000 boxes in 1930. Exports from the United States for 1930-31 amounted to 1,370,000 boxes, the United Kingdom taking almost twice the quantity imported in 1929-30. Direct exports from Porto Rico to Europe amounted to 92,000 boxes. Palestine which produces a high-quality grapefruit exported 57,000 boxes in 1930-31, and South Africa about 100,000.

It is expected generally that there will be a further increase in the demand for grapefruit although it does not appear that demand will increase as fast as production. This, together with the prospect that the general price level will continue below the 1921-29 average, points towards materially lower grapefruit prices than the average of recent years. Further prices of summer grapefruit are likely to be better than those of the winter fruit.

The position of the industry in Trinidad is strong in view of the fact that the cost of producing grapefruit in the Colony compares favourably with most other countries. Trinidad grapefruit also has an exceptional flavour and juice content which may help it to command higher prices. Such prices, however, will not be realised unless the standard of the fruit is maintained. With the present interest, however, which is shown in the crop and the facilities which have been provided for packing it, there is no reason why this should not be achieved.

* United States of America Department of Agriculture, *Miscellaneous Publication* No. 137.

GROS MICHEL AND PISANG EMBUN.

In connection with a note under the above title in the March number of this journal (p. 87), my attention has been called to the fact that Pisang Ambon from Java was sent to Dominica by Kew as long ago as 1898. In his Annual Report for 1902-03, as Curator of the Botanic Station, Dominica, Mr. Joseph Jones notes that the collection of named varieties of bananas received from Kew during the previous four years numbered twenty-eight, and that several of them were identical with the best local varieties. He goes on to state specifically that: "The Pisang Ambon of Java, if not identical with, is very similar to, our local La Rose banana". La Rose of Dominica is known to be Gros Michel, and credit is therefore due to Mr. Jones for having suggested the identity of the Eastern and the West Indian forms of this banana, almost a quarter of a century before a tropical interest in Panama Disease revived the question of the origin of Gros Michel.

I regret the omission of this acknowledgement from my note, the more so as the survivors of the Kew collection mentioned formed at a later date an important nucleus for the present Imperial College collection. At the commencement of the College banana breeding programme some varieties were obtained direct from Dominica, and others from Trinidad and other parts of the West Indies, to which they had been distributed originally by Mr. Jones himself, so that we are indebted to his work on these varieties for our own start.

E. E. C.

CONTRIBUTION TO THE KNOWLEDGE OF WITCHBROOM DISEASE.

By Gerold Stahel.

[*This paper which appeared in December, 1919, as Bulletin No. 39 of the Department of Agriculture, Surinam, has been translated from the Dutch by B. G. Montserin, M.Sc., of the Department of Agriculture, Trinidad. It includes an account of certain aspects of witchbroom disease, notes on its biology, and observations on its control.*]

I. Introduction.

Two important points with regard to Witchbroom disease, still require investigation :—firstly, whether indurated pods are also caused by the Witchbroom fungus, and secondly, how *Marasmius perniciosus* enters the plant. Success in producing induration of pods by inoculating with *Marasmius* spores from mushrooms on dead brooms would establish at what time after infection the pods become indurated, and such knowledge would be invaluable for controlling the disease.

In the Yearbook, 1915, I reported inoculation tests of a total of 380 cacao flowers and ovaries with spores of *Marasmius perniciosus* in an attempt to determine whether indurated pods could be produced in this way. Of seven fruits that matured, two were entirely diseased; the remaining five, however, were quite healthy. The results were altogether insufficient to establish the proof of this point.

Since the publication of *Bulletin* No. 33, much literature on Witchbroom disease has been published, especially with regard to control, and in the Surinam and Curacao Journal of Agriculture, *West Indië*, reports with regard to this subject were made by :

J. F. van Emden	.. in 1916—No. 3
W. K. A. Moll	.. in 1916—No. 4
W. M. Braumuller	.. in 1917—No. 1
A. J. Polak ..	.. in 1917—No. 1
J. F. van Emden	.. in 1917—No. 1
D. S. Huizinga	.. in 1917—No. 1
J. A. Liems ..	.. in 1917—No. 4
E. Zeiler ..	.. in 1918—No. 2
G. Stahel ..	.. in 1918—No. 4

II. The Penetration of *Marasmius perniciosus* into the Plant.

The infection experiments of Went (1904), Rorer (1913), and the writer (1915), have shown that cacao buds cannot be infected with mycelium grown from living brooms. When it was demonstrated (Went, 1904, p. 24) that infection depended on the presence of basidiospores of *Marasmius perniciosus* (Stahel, 1915, p. 10), two theories were held : either that the germ tube penetrated the cuticle or that it entered through the stomata of the plant. There was very little likelihood of infection through wounds.

The epidermis of the young vegetative and reproductive buds like that of the young fruits is covered with glandular hairs which emerge from one or more stalk cells and from a many-celled tissue gland bud. The young vegetative and reproductive buds are also covered with thick-walled, stellate hairs which make examination of the epidermis by tangential sections very difficult. The stellate hairs on young pods are, however, entirely absent, thus making it easier to observe the method by which the *Marasmius* germ tube enters the plant.

Fully opened stomata can be identified in a resting-bud on leaves 2 to 3 mm. long. Stomata were never found on the ovary, except immediately after fertilization when the ovary just commences to enlarge. On young fruits the stomata are fairly widely disposed (200 to 300μ apart), very often in groups of 2 to 4 together. They frequently occur on small, flattened, cushion-like elevations. Usually many of these cushions may be dead and separated from the living tissue by a watchglass-shaped cork layer.

In order to determine whether the *Marasmius* germ tube could penetrate the ovary the following experiment was carried out : the naked ovaries of freshly collected cacao flowers which had been stripped of calyx, corolla and stamens were placed for 1 to 2 minutes beneath a spore-producing *Marasmius* mushroom and then put into a moist-chamber. Under these conditions the spores germinated normally as exemplified by the germination test conducted with a parallel series on glass slides in a moist-chamber (*see* section V). Penetration of the cuticle by the germ tubes was never observed either in tangential—or cross—sections. Nor could any sign of *Marasmius* hyphae be detected in the tissue of the ovary.

If infection of the ovaries with *Marasmius* spores follows the same course as infection of the young fruits, then the spores should develop in the ovaries in much the same way as they do in the young fruits where it will be seen from tangential—and cross—sections that the germ tubes, in just a few hours, have entered the stomata and penetrated further into the tissue of the epicarp. (Pl. VI, fig. 142.)* Similarly I observed the entrance of germ tubes through the stomata of full-grown fruits and leaves but could not make sure that they grew further into the full-grown organs.

I was not fortunate enough to observe the entrance of germ tubes into stomata on the very young leaves because the dense covering of hair seldom allowed the stomata to be seen. There is absolutely no reason to doubt, however, that here also the germ tubes use the stomata as entry ports.

Since spores may germinate in water in an hour, the germ tubes of spores adjacent to the stomata may gain entrance in a few hours.

* None of the plates referred to in the text have been reproduced as the blocks were not available.

III. The Induration of the Cacao Pods.

In the foregoing section it was shown that the germ tubes of *Marasmius perniciosus* enter through the stomata of the young fruits and proceed to grow between the parenchyma cells. Thus there is proof that the fruits can be infected by the Witchbroom fungus. Infection tests in the field should disclose more with regard to the development of the disease in fruits of different ages.

The inoculation of the 380 ovaries, in 1915, was carried out in the following manner: the flower was tied with a piece of string in such a way that the ovary pointed upwards. After artificial pollination, a spore-producing *Marasmius* mushroom was placed over the stigma. The whole was then covered with a small crucible and kept moist for two days. As previously reported, five of the seven fruits that matured were perfectly healthy while the remaining two were so indurated that no portion was disease-free. These two fruits attained a length of only 6 cms. Since ovaries without stomata cannot be infected, the result obtained is explained in that the two fruits became diseased through infection at a very young stage when they had been already provided with stomata.

In 1917, further inoculation experiments were conducted; on this occasion ovaries were no longer used, but only fruits of different ages were inoculated. At first they were inoculated like the flowers. A spore-producing mushroom was placed over the fruit and the whole was then covered for two days with a test tube. After inoculation No. 15, the *Marasmius* spores were put in water and applied to the fruit with a sterile brush. Abundant pure spore material was obtained by inverting *Marasmius* "caps" overnight upon flamed coverglasses in a moist chamber. With a brush the inoculation is much more quickly and easily done, while fewer mushrooms are required since one coverglass would supply sufficient spores for 4 to 6 inoculations.

An area ½ to 1 cm. in diameter on the fruit was in each case covered with the spores and the location and orientation of the inoculated area were recorded in a sketch. Parallel with the inoculated series, other fruits of about the same size were labelled (No. 1a, &c.) to serve as controls being uninoculated but, like the inoculated fruits, covered with a test tube for two days.

Almost all inoculations were made on the Forastero variety.

The fruits were picked shortly after the diseased (inoculated) area had died out. A longitudinal cut was made through each diseased fruit in such a way that the sound and the infected areas would appear in the cut surface. In each case a sketch was made of the spreading disease tissue at this stage. In order to remove any doubt as to the presence of *Marasmius* infection, microscopic preparations were made from the diseased fruits in every instance.

The controls as well as the inoculated fruits which did not become indurated were not picked until quite ripe.

Of a total of 174 inoculations, 155 were made on the fruits and 19 on the flowers. Sixty-four of the 155 inoculated fruits and 52 of the controls were finally left. The others dropped off or were picked by mistake by the labourers. The number was large enough, however, to serve the purpose for which it was required.

The results of the inoculation experiments are shown in Tables I and II. (*See* pp. 174-175.)

Of the 64 inoculated fruits which remained only 39, *i.e.*, about 60 per cent. were diseased. Considering the infected fruits by their relative lengths at the time of inoculation, instead of by number, gives a different aspect to the results.

Relative length of fruit at time of inoculation.	Healthy.	Skin only diseased.	Up to half of seeds diseased.	More than half of seeds diseased.
More than ¾ full length	9	2	—	—
½ to ¾ full length	5	3	—	—
¼ to ½ full length	7	4	10	6
Less than ¼ full length	4	—	—	14

The significance of these figures would be even more striking were the length-groups expressed in percentages, to the nearest multiple of ten.

Relative length of fruit at time of inoculation.	Healthy.	Skin only diseased.	Up to half of seeds diseased.	More than half of seeds diseased.
More than ¾ full length	80	20	—	—
½ to ¾ full length	60	40	—	—
¼ to ½ full length	30	10	40	20
Less than ¼ full length	20	—	—	80

It is thus seen that infection can produce indurated pods only when the fruits are less than half their normal length. If the fruits are more than half their normal length, then only the "skin" at the point where fruit infection took place can be affected (*see* Pl. VII).

Only after the infection of fruits less than 2 cm. long will swellings be clearly seen as shown in Pl. VI and VIII in the Witchbroom Bulletin of Van Hall and Drost (1909). (*See* also Pl. VIII, fig. 5, of this Bulletin). If the fruits are longer than 2 cm. at the time of infection then no external symptom is noticed on the fruit until the diseased tissue, *i.e.*, at the point of infection, begins to die out. The fruits were examined once each week. It was quite noticeable that fruits which had been

apparently normal and healthy a week before would develop a large dead area. Microscopically it was always possible to observe how far the mycelium had penetrated into the tissue, while macroscopically also, half grown fruits cut across the diseased tissue showed, here and there, dead, darkened cell-groups of 1-3 mm. in diameter, as already reported by Van Hall and Drost.

It is well known to planters that the greatest numbers of indurated pods are found at the beginning of the cacao crop in May and June. This illustrates the fact that infected fruits ripen sooner, while those that had been infected at a very young stage (less than 2-3 cm. long) die before attaining maturity.

The proof of this is given in our inoculation records.

Twenty infected fruits which at the time of inoculation were 25-75 mm. long were picked indurated after 91 days at about full-grown size; the twenty control fruits of the same length reached maturity after 118 days.

As already reported in Bull. 33, the cut surfaces of diseased pods, after about 12 hours, are covered with a fine white mycelium which in a few days forms a very thick white felt which subsequently becomes crimson. It is remarkable, however, that this mycelium on the cut surfaces of very young fruits, only a few centimetres long, in which the intercellular mycelium can be observed everywhere with the aid of a microscope, never grows out even after the lapse of many days.

IV. The Diseased Flower Cushions.

Van Hall and Drost have already referred to the diseased flower-cushions which they call "starblooms." By "starblooms" in Surinam is understood flower-cushions with very many flowers. Such flower-cushions are not only found in Surinam but also, for instance, in Trinidad (Rorer, 1911) where Witchbroom disease does not exist. Very often the whole stem is covered with it. This phenomenon has nothing to do with Witchbroom disease. There are starblooms also which originate through infection of *Marasmius perniciosus*. Such diseased starblooms were first illustrated and reported by Van Hall and Drost (1909, Pl. IX, fig. 7). Healthy pedicels as well as the stalks of the common starblooms are about ½ mm. thick and are limp. On the other hand diseased pedicels are three times as thick and stand erect. *Marasmius*-diseased cacao flowers are not shed with the pedicels from the inflorescence as in the case of healthy unfertilized flowers, but they remain with the inflorescence even after having died. If the name "starblooms" is to be retained for these diseased inflorescences, they should be called "Witchbroom-" or "*Marasmius*-diseased starblooms" to distinguish them from the common starblooms of non-parasitic origin. Frequently the diseased inflorescences develop into normal-sized Witchbrooms because the end of the sprout (cincinnus) suddenly forms a vegetative internode instead of a flower; this offshoot of the flower is capable of further growth in a purely vegetative manner. The vegetative parts are bilateral and seldom arise radially (*see* Stahel, 1918). When several sprouts of a diseased flower-cushion develop together into witchbrooms, they then form as a whole a typical 'witches' broom (heksenbezem).

Nevertheless there is hardly any doubt that *Marasmius perniciosus* is the cause of Witchbroom disease (krullotenziekte), starblooms and the witches' brooms (heksenbezems) from which organs it develops, *e.g.*, as *Marasmius* mushrooms on the dead organs. To verify this point I have conducted inoculation experiments with flower-cushions.

Nineteen flower-cushions whose sprouts bore only very young flower-buds were inoculated with *Marasmius* spores according to the technique outlined in the preceding section for the inoculation of young fruits. The inoculated series as well as 19 controls were covered with a crucible and kept moist for two days. All of the controls remained healthy. On the other hand, 5 of the 19 which had been inoculated became diseased. The majority of the remaining 14 inoculated flower cushions failed to develop into flowers even after several months.

Inoculation No. 4	14th June, 1917	Inoculated.
	4th Aug., 1917	Many diseased pedicels and few young fruits.

Control No. 4 healthy.

Inoculation No. 63	21st Apr., 1917	Inoculated.
	11th May, 1917	Diseased pedicels and flowers.
	7th June, 1917	Inflorescence developed into Witchbroom.
	4th Aug., 1917	Entire flower-cushion dead.

Control No. 63 healthy.

Inoculation No. 68	22nd Apr., 1917	Inoculated.
	31st May, 1917	One pedicel diseased.
	4th Aug., 1917	Many diseased and dead flowers and a few witch-brooms (Pl. IV).

Control No. 80 healthy.

Inoculation No. 89	28th Apr., 1917	Inoculated.
	31st May, 1917	Two pedicels diseased.
	12th June, 1917	The two pedicels still living, the flowers dead.

Control No. 89 healthy.

In inflorescences also, as in the case of witch-brooms and indurated pods, only the young, rapidly growing parts can be infected. The fungus cannot develop in the full-grown tissue nor along the cambium.

In figs. 8 and 9, Pl. VII, radial sections of flower cushions may be seen. The spread of the disease with *Marasmius* hyphae permeating the tissue is indicated by the dark area. After 1-2 months the diseased, full-grown tissue is generally killed and can form *Marasmius* mushrooms during rainy weather. As illustrated in the two diagrams, it is only necessary to remove the diseased flower cushions by a deep tangential cut to be sure that no *Marasmius*-containing tissue is left behind to produce mushrooms later on.

There are trees in our cacao plantations on which numerous "witches'" brooms (heksenbezems) are always present while on neighbouring trees the inflorescences only seldom show the disease.

I have never been able to find diseased inflorescences on *Theobroma bicolor*, although in *T. bicolor* water shoots develop very vigorous witchbrooms. My experiments have shown that very vigorous witchbrooms could be produced from inoculating terminal buds of young *bicolor* plants, whereas with lateral branches and inflorescences they could not be produced successfully. In the latter case, the buds either die after inoculation or develop into healthy organs. On old *T. bicolor* trees, however, I have occasionally found very small (only a few cms. long), dead bilateral witchbrooms which had been killed at a very early age, but where, nevertheless, the side buds had already burst. This indicates that the parasitic *Marasmius* mycelium has a worse effect on the tissue of T. *bicolor* than on that of the ordinary cacao. *T. bicolor* suffers very little as a result of Witchbroom disease, but it is clear that this is not due to immunity but perhaps, to its hypersensitivity to *Marasmius perniciosus*.

As I have already reported in Bull. 33, it seems quite improbable that immune cacao varieties will be found since two other types of cacao *Theobroma bicolor* and *Theobroma speciosum* have been shown to be susceptible to Witchbroom disease. It is not impossible, however, to find varieties among our plantation cacao which would be only slightly affected by the disease on account of their hypersensitivity.

Many deformed and dwarfed fruits develop from the *Marasmius*-diseased flower cushions (Went, 1904, Pl. II, fig. 6 ; Stahel, 1918, Pl. XX). The diseased fruits which had been infected in the fruit cushions always stand upon hypertrophied stems and are thus easily distinguished from fruits which are directly infected by *Marasmius* spores when in the young-fruit stage. All of the diseased organs are totally ramified by parasitic *Marasmius* hyphae. Such pods do not produce seeds and on this account are called "Male Cacao" in Surinam. It must be noted, however, that on some plantations there are trees which bear seedless pods also known as "Male Cacao" but they are in no way connected with Witchbroom disease. Thus it is also necessary to distinguish between the ordinary "Male Cacao" and Witchbroom diseased "Male Cacao".

Fruits which have been infected from a diseased inflorescence through a pedicel or fruit-stalk may be termed *indirectly infected fruits* in contradistinction to *directly infected fruits* which are infected directly by *Marasmius* spores. Among directly infected fruits we may again distinguish those with swellings, *i.e.*, fruits which at the time of infection were not longer than 2 cm., and those without swellings. By far, most of the indurated pods belong to this latter category since this symptom results from infection of young fruits one-half to two and one-half months old.

V. Notes on the Biology of *Marasmius perniciosus*.

Since infection is only possible with basidiospores of *Marasmius perniciosus*, it is necessary to have plenty of fresh *Marasmius* mushrooms for inoculation experiments. This may be obtained either from the mycelium in pure cultures or from the dead brooms.

As already reported in *Bull.* 33, the mycelium of *Marasmius perniciosus* in agar cultures forms a thick and compact felt which is white at first but subsequently becomes spotted with dark crimson. Previously I could not confirm Rorer's report (1913, p. 10) that the *Marasmius* mycelium became yellow in culture. However, when I grew a few cultures outside the laboratory in full daylight, the mycelium soon changed to a citron-yellow colour. I never succeeded in obtaining mushrooms either from a witchbroom or from agar cultures even though they were kept in full daylight for several weeks.

Marasmius mycelium separated readily and completely from the agar cultures. When hung in porcelain vessels under a *Ficus* tree it began after 2-3 days to change its colour to a dark crimson, and after ten days of rainy weather it was covered with mushrooms of *Marasmius perniciosus*. As the mycelium used in these experiments was grown from green, living witchbrooms resulting from inoculation trials with *Marasmius* spores, and as the mycelium produced from green witchbrooms corresponded in every detail with that produced from the basidiospores of *Marasmius perniciosus* it was further proved that *Marasmius perniciosus* was undoubtedly the true cause of Witchbroom disease. This pure mycelium exposed to the air might conceivably have become contaminated with *Marasmius* spores and the mycelium arising from such spores have produced the mushrooms, but this possibility was very remote. In view of the two already established proofs, we hope to be able to advance more definite proof in this regard. Before long, I expect that mycelium cultured from green witchbrooms here would produce *Marasmius* mushrooms in Holland, in which case definite proof will be established.

The method of growing the mushrooms from dead witchbrooms is much the easier and cheaper. For this purpose I had a number of tables constructed of bamboo slats beneath a shady *Ficus* tree. These tables were covered with witchbrooms which found conditions similar to those in the tops of cacao trees.

In August, 1916, these tables were covered with green witchbrooms from which the leaves had been removed. Soon after the first showers, a few *Marasmius* mushrooms could be observed here and there on the dead witchbrooms. Up to

January, 1917, the number of mushrooms which appeared was very small. On the other hand, later on, in rainy weather from March to June these witchbrooms produced a large number of *Marasmius* sporophores (Pl. I–II). Indurated pods were placed on these tables and they likewise produced mushrooms during the main rainy season (Pl. III, fig. 1), although not as abundantly as the witchbrooms. Some of these witchbrooms produced *Marasmius* mushrooms up to February, 1918—*i.e.*, one and one-half years later.

On black witchbrooms a few months old, it will be observed after a half day of rain how round, dark-crimson buttons appear through the black bark of the dead witchbrooms. One day later in rainy weather they develop into white or crimson-tinted mushrooms. If rain continues for more days without allowing the brooms to dry, the *Marasmius* fructifications will disappear completely. The mushrooms rot at a young age under such conditions.

Mushrooms may be obtained in this way only during rainy weather. I have already pointed out that we will never succeed with the moist-chamber. I have made attempts by putting dead brooms on a bamboo table and keeping them moist by wetting 4 to 5 times per day with a watering can. I succeeded thus in obtaining mushrooms which, however, remained small and failed to develop to normal size. It would seem that the dry air inhibits their development. If these very young spherical mushrooms attached to the brooms are then placed in a moist chamber they will develop into normal-sized mushrooms. Thus in the dry season also I could secure an abundant supply of *Marasmius* spores.

To obtain pure spore material I proceeded as follows: brooms with young mushrooms, 2 to 4 mm. in diameter, were selected from the bamboo tables, broken into pieces 2 to 5 cm. long and inserted with a pin on a cork plate so that a mushroom was located a few millimetres away from the plate. The whole was then put into a moist-chamber, the spores being caught on flamed coverglasses.

In Table III I have appended a few observations with regard to the development and longevity of some *Marasmius* mushrooms in moist chambers. It will be observed that mushrooms can commence spore-production when the pileus is only 2 to 3 mm. in diameter. They will continue producing spores for 1 to 2 days after they are fully grown (Pl. V). As clearly shown in the table the pileus shrinks before it is dead.

In a study of *Marasmius* spores it is very remarkable that the hymenium produces very little or no spores during the morning hours. The greatest quantities of spores were discharged between 6 p.m. and midnight. This is illustrated in Plate V. After every three hours the coverglasses beneath the numbered mushrooms were renewed. The daily fluctuation in spore-production could not be controlled by keeping the mushrooms in permanent darkness. Although I did not obtain further proof it seems very probable that the variation in spore production is caused by diurnal temperature changes. The greatest spore-production occurs five to seven hours after the highest daily temperature while the least output takes place five to seven hours after the lowest daily temperature.

On page 16 of *Bull.* 33 I have pointed out that spores die after remaining for one hour in a desiccator. I have repeated these experiments. If these spores are collected on a coverglass and desiccated for one hour, they fail to germinate in a damp atmosphere unless they are very densely sown on the coverglass. If, however, the spores are sown very thickly, *i.e.*, at a distance approximately less than 50μ, then they will germinate after they have remained longer than one hour in the desiccator.

Thickly sown.	In the desiccator.	Exposed to air.
Damp at inception	—	2 very good, 1 good, 1 failed to germinate.
1 hour dry	2 good, 2 failed to germinate	2 very good, 1 bad, 1 failed to germinate.
5 do.	1 good, 2 middling, 1 failed to germinate	2 middling, 2 failed to germinate.
10 do.	1 very good, 1 bad, 2 failed to germinate	2 middling, 2 failed to germinate.
15 do.	All 4 failed to germinate	1 good, 1 bad, 2 failed to germinate.
20 do.	All 4 failed to germinate	All 4 failed to germinate.
25 do.	All 4 failed to germinate	All 4 failed to germinate.
30 do.	All 4 failed to germinate	All 4 failed to germinate.
35 do.	All 4 failed to germinate	All 4 failed to germinate.

Thus thickly sown *Marasmius* spores exposed to desiccation for 15 hours or to air for 20 hours fail to germinate. An attempt was made to induce thinly sown spores to germinate by stimulation with carbon dioxide and oxygen but it proved valueless. Young cacao pods were shaved and the shavings agitated with water and filtered. Small quantities of the filtrate were allowed to dry on coverglasses. On such coverglasses very thinly sown spores also failed to germinate. It was observed that spores immediately dampened on the coverglass, even when thickly sown, often failed to germinate.

VI. Control.

With a knowledge of the conditions favourable to the development of *Marasmius perniciosus* the most practical measures of control may be suggested. It is felt that the most efficient method for Witchbroom control, over which there is so much controversy, has at last been

realized. It is now known that this disease which has been so very destructive to Surinam cacao plantations for the past 15 to 20 years can be easily and economically controlled. Results obtained by many planters, who had carefully followed the control measures advised, have supplied evidence by way of increased yields that cacao cultivations in Surinam could be made profitable with proper control of Witchbroom disease.

Past experience has clearly demonstrated that pollarding is a most expensive method (*see Bull.* 33, p. 21), since the same results may be obtained in a cheaper and entirely safe way. Although it has yielded good results on some plantations it is inadvisable to follow this method. Pollarding has not been done for several years. Similarly, the second method, *i.e.*, spraying with Bordeaux Mixture, has not been used for some time. In 1915, the writer (Bull. 33, p. 24) gave the following advice with regard to the control of Witchbroom disease: "If searching and subsequent removal alone is not sufficient, then this measure must be supplemented by spraying with Bordeaux Mixture." Since that time, the results obtained by many planters have shown that, with the careful removal of witchbrooms and other diseased organs, spraying may be omitted. (*See* also articles in *West Indië*, by J. F. Van Emden, 1916 and 1917, W. M. Braumuller, 1917, J. W. Liems, 1917, and E. Zeiler, 1918.)

The present simple method entails the careful removal, every 3 to 4 weeks, of witchbrooms, indurated pods and diseased cushions which should be buried, burned or taken away from the field. Annual pruning will render the trees more open, and an occasional light pruning will lessen the number of infection buds thereby assisting in the control of the disease.

It is quite remarkable that such a simple and convenient method had not been adopted from the outset but was eventually arrived at through a more costly and hazardous measure. The pollarding and spraying method undoubtedly included the removal of diseased organs, but it was formerly believed that the regular removal of diseased organs alone could not prove sufficient. Most of the plantations had at first adopted one or other of the former control methods only to revert afterwards to the present system. In 1916, plantation "Mon Souci", with 270 acres of bearing cacao trees, was one of the most heavily-diseased plantations; in some fields more than 90 per cent. of the pods were lost through induration. This plantation began to use the new method in 1916. Within 2 to 3 months of the first removal of diseased organs and thorough pruning of the trees* a large number of witchbrooms was found, while a half-year later the approximate number of witchbrooms was not greater than on the plantations where this method had been used for years. The witchbrooms which appeared during the first 2 to 3 months developed from buds which already had been infected prior to the removal of diseased organs.

E. Zeiler (*West Indië*, 1918, p. 74) holds the view that with removal of witchbrooms and other diseased organs every 2 to 3 months or oftener, it is not necessary to have the cuttings collected and destroyed. In *Buil.* 33, as well as above the writer has recommended the removal of *Marasmius*-diseased organs every 3 to 4 weeks because mushrooms can be found on witchbrooms which have just died as well as on those cut off and dropped on the ground. Moreover, as has been pointed out in section V—during the first 2 to 3 months after having died and also during rainy weather the witchbrooms and indurated pods produce few mushrooms but these appear in large numbers later on. Zeiler also reported that he obtained good results in Witchbroom control by less stringent methods. Plantations are warned, however, against the adoption of such methods. One plantation may be drier, more open and less subject to the risk of infection from neighbours than another; it may thus yield good results with less stringent application of control measures, while the results on another plantation would be altogether unsatisfactory. Because less strict application of the control measures proves efficient for one year, it does not follow that this will be the case the following year.

Very careful removal of the witchbrooms is necessary for a few months when the young pods on the trees are less than half-grown, thus chiefly in December and January and also in July and August. As shown in section III, infection is most destructive to the young fruits since they become completely indurated; if they have attained ¼ their full-grown length before infection takes place then most of the seeds remain healthy. If the fruit is half-grown the fungus cannot penetrate to the seeds but will only cause a disease lesion on the bark of the pod. *Every overlooked witchbroom can cause the loss of numerous cacao pods when there are many young and not yet half-grown fruits on the tree.*

Special care should be exercised in removing the diseased organs during and after an abnormally wet dry-season. In years with normal or with particularly severe dry-seasons, the *Marasmius*-diseased cacao fields should be considerably free from infection where the regular removal of witchbrooms has been practised. New buds cannot be infected during such periods because overlooked witchbrooms cannot bear mushrooms on account of the drought. At this time many resting buds which had been infected during the previous rainy season begin to burst and should be removed. A plantation very carefully cleaned of witchbrooms is therefore much more healthy at the end of a severe drought, than the same apparently equally well cleaned plantation at the

* With severely infected trees this pruning must be so thorough that nearly all of the one-year old branches bearing witchbrooms must be removed.

end of a severe rainy-season, because during the dry period the number of infected resting buds is greatly reduced. The health of Witchbroom-affected plantations becomes poor during the rainy-season, recovering successively during the dry-season. This is illustrated by a few figures for Plantation "La Liberte" supplied by J. W. Liems (*West Indië*, 1917, p. 138).

In the absence of a severe dry-season, as in 1917, then Witchbroom disease will be very serious during the following year, as was really the case in 1918. On Plantation "Marienbosch", two witch-brooms per tree were gathered in eight special fields from July to September, 1917; in 1918, however, 30 witchbrooms per tree were gathered during the same period.

Plantation "La Liberte."

Month.	Average number witchbrooms per tree, 1909-1916.	Average cost of removing witch-brooms and black pods per tree.
December-January	0.24	0.67 cents.
February-March	0.31	0.66 do.
April-May	0.41	0.73 do.
June-July	0.91	0.90 do.
August-September	2.42	1.60 do.
October-November	0.67	1.20 do.
Per year	4.96	5.76

The following figures demonstrate the effect of Witchbroom control upon yield:

Year.	Average marketable product per tree in kilograms.	Fields No.	Remarks.
1908-11	0.6	4, 6, 8	Before control of Witchbroom disease.
1912-15	1.2	4, 6, 8	Since 1912, removing brooms and regular pruning; sprayed Bordeaux once, 1914.
1916-18	1.9	4, 6, 8	Regular removal of brooms.

The average yield of the whole of Plantation "De Maasstroom" follows:

Year.	Average Annual Yield.	Number of trees.	Remarks.
1890-99	336 bags (of 100 K.G.)	41,500	Before Witchbroom.
1900-09	168 do. do.	—	Before control.
1910-15	248 do. do.	28,200	Brooms regularly removed.
1916-18	431 do. do.	28,200	Brooms regularly removed.

Zeiler (*West Indië*, 1918, p. 73) gives the following figures for Plantation "Sorgvliet":

Year.	Mean annual production (bags of 100 K.G.)	Number of trees (approximate).	Remarks.
1904-10	88	30,000	Before Witchbroom control.
1911-12	105	30,000	Some trees pruned, others sprayed.
1913-15	209	30,000	Brooms regularly removed.
1916-17	283	30,000	Brooms regularly removed.

The production of Plantation "De Morgenstond" from 1897 was:

Year.	Average yield (bags of 100 K.G.)	Number of trees. (approximate).	Remarks.
1897-1900	841	90,000	Before Witchbroom.
1901-1912	271	70,000	Before control.
1913-1918	419	47,000	Witchbrooms removed.

On the Plantations "Maasstroom", "Mon Souci", "Sorgvliet" and "Morgenstond", the cost of removing witchbrooms and other diseased organs was 6 to 10 cents per tree per annum. The cost of first pruning and removal of diseased organs of the very bad trees on Plantation "Mon Souci" was 5 to 6 cents per tree. By an increased yield of about 0.20 K.G. per tree, Witchbroom control fully repays. The above data for yield on the few plantations indicate that carefully executed control of Witchbroom disease repays doubly and several times more by the increased returns.

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Table I.

Inoculated No.	Inoculated. Date.	Length of fruit in mm.	Picked. Date.	Length of fruit in mm.	Remarks. I.	II.	III.	IV.	V.	VI.
8	17th March, 1917	14	9th August, 1917	150	I	....	....	....	....	....
10	18th March, 1917	15	19th May, 1917	90	....	....	....	....	I	....
15	19th March, 1917	25	9th August, 1917	175	I	....	....	....	....	....
17	19th March, 1917	20	9th August,1917	200	I	....	....	....	....	....
19	20th March, 1917	95	18th August, 1917	125	I	....	....	....	....	....
23	20th March, 1917	65	23rd July, 1917	150	....	....	....	I	....	....
24	20th March, 1917	60	9th August, 1917	135	I	....	....	....	....	....
26	20th March, 1917	53	28th July, 1917	115	I	....	....	....	....	....
27	20th March, 1917	65	10th July, 1917	175	....	....	....	....	....	I
37	22nd March, 1917	49	25th June, 1917	142	....	....	....	....	....	I
45	23rd March, 1917	63	9th August, 1917	130	I	....	....	....	....	....
51	30th March, 1917	115	18th July, 1917	160	I	....	....	....	....	....
55	30th March, 1917	7	20th June, 1917	148	....	....	....	....	....	I
61	2nd April, 1917	14	18th July, 1917	128	....	....	....	....	....	I
65	11th April, 1917	130	9th August, 1917	200	I	....	....	....	....	....
66	22nd April, 1917	16	14th June, 1917	54	....	I	....	....	....	....
70	22nd April, 1917	37	18th July, 1917	210	....	....	....	....	....	I
71	22nd April, 1917	17	18th July, 1917	185	....	....	....	....	....	I
73	24th April, 1917	95	9th August, 1917	115	I	....	....	....	....	....
75	24th April, 1917	65	18th July, 1917	155	I	....	....	....	....	....
77	24th April, 1917	13	18th July, 1917	155	....	....	....	....	....	I
78	24th April, 1917	35	10th July, 1917	140	....	....	....	....	....	I
81	26th April, 1917	36	4th August, 1917	155	....	....	....	....	....	I
82	26th April, 1917	70	9th August, 1917	170	....	....	....	I	....	....
83	26th April, 1917	50	23rd July, 1917	140	....	....	I	....	....	....
84	26th April, 1917	65	23rd July, 1917	140	....	I	....	....	....	....
85	28th April, 1917	40	28th July, 1917	160	....	....	....	....	....	I
88	28th April, 1917	14	4th August, 1917	165	....	....	....	....	....	I
102	7th May, 1917	122	3rd October, 1917	175	I	....	....	....	....	....
103	7th May, 1917	47	9th August, 1917	180	....	....	....	....	I	....
108	12th May, 1917	20	23rd August, 1917	125	....	....	....	....	....	I
109	12th May, 1917	105	30th July, 1917	145	....	I	....	....	....	....
110	12th May, 1917	30	16th June, 1917	77	....	I	....	....	....	....
112	12th May, 1917	65	23rd July, 1917	180	....	....	....	I	....	....
115	14th May, 1917	60	23rd August, 1917	150	....	....	I	....	....	....
116	14th May, 1917	55	23rd August, 1917	150	....	....	....	I	....	....
117	14th May, 1917	35	30th July, 1917	145	....	....	....	....	I	....
118	14th May, 1917	120	23rd July, 1917	165	I	....	....	....	....	....
121	14th May, 1917	80	23rd August, 1917	140	....	I	....	....	....	....
122	15th May, 1917	55	23rd August, 1917	145	....	....	....	....	I	....
123	15th May, 1917	35	30th July, 1917	142	....	....	....	....	I	....

I. Healthy.
II. Only skin diseased.
III. $\frac{1}{4}$ of the seeds diseased.
IV. $\frac{1}{2}$ of the seeds diseased.
V. $\frac{3}{4}$ of the seeds diseased.
VI. All of the seeds diseased.

Table I.—*Contd.*

Inoculated No.	Inoculated. Date.	Length of fruit in mm.	Picked. Date.	Length of fruit in mm.	Remarks. I.	II.	III.	IV.	V.	VI.
126	15th May, 1917	60	23rd July, 1917	160	....	....	....	....	....	1
128	15th May, 1917	50	23rd July, 1917	165	....	....	....	....	....	1
130	16th May, 1917	40	30th August, 1917	140	....	....	....	1	....	....
133	16th May, 1917	50	13th September, 1917	225	1	....	....	....	....	....
134	22nd May, 1917	45	9th August, 1917	175	....	....	....	1	....	....
136	22nd May, 1917	85	15th August, 1917	170	....	1	....	....	....	....
137	22nd May, 1917	75	9th August, 1917	170	....	....	....	1	....	....
138	22nd May, 1917	45	9th August, 1917	145	....	....	....	....	....	1
141	22nd May, 1917	50	28th August, 1917	172	....	....	....	1	....	....
143	23rd May, 1917	105	23rd August, 1917	185	1	....	....	....	....	....
145	25th May, 1917	45	23rd August, 1917	160	1	....	....	....	....	....
146	25th May, 1917	65	3rd September, 1917	165	1	....	....	....	....	....
149	25th May, 1917	55	3rd October, 1917	160	1	....	....	....	....	....
150	25th May, 1917	95	13th September, 1917	155	1	....	....	....	....	....
155	26th May, 1917	90	13th September, 1917	160	1	....	....	....	....	....
156	26th May, 1917	105	13th September, 1917	145	1	....	....	....	....	....
158	12th July, 1917	135	26th September, 1917	175	1	....	....	....	....	....
160	12th July, 1917	140	26th September, 1917	190	....	1	....	....	....	....
161	12th July, 1917	100	3rd October, 1917	155	....	1	....	....	....	....
169	14th July, 1917	160	3rd October, 1917	169	1	....	....	....	....	....
170	14th July, 1917	130	13th September, 1917	135	1	....	....	....	....	....
171	14th July, 1917	120	3rd October, 1917	180	....	1	....	....	....	....
173	14th July, 1917	140	3rd October, 1917	210	1	....	....	....	....	....

I. Healthy.
II. Only skin diseased.
III. ¼ of the seeds diseased.
IV. ½ of the seeds diseased.
V. ¾ of the seeds diseased.
VI. All of the seeds diseased.

Table II.

Control No.	Marked. Date.	Length of fruit in mm.	Picked. Date.	Length of fruit. in mm.	Remarks.
12a	18th March, 1917	45	18th July, 1917	125	Ripe and healthy.
15a	19th March, 1917	23	9th August, 1917	140	Do. do.
16a	19th March, 1917	47	4th August, 1917	195	Do. do.
18a	19th March, 1917	25	23rd August, 1917	175	Do. do.
23a	20th March, 1917	85	23rd August, 1917	160	Do. do.
29a	20th March, 1917	75	4th August, 1917	150	Do. do.
43a	22nd March, 1917	66	9th August, 1917	155	Do. do.
46a	24th March, 1917	100	18th July, 1917	130	Do. do.
49a	24th March, 1917	95	18th July, 1917	150	Do. do.
50a	24th March, 1917	110	18th July, 1917	165	Do. do.
52a	30th March, 1917	120	18th July, 1917	155	Do. do.
53a	30th March, 1917	80	9th August, 1917	150	Do. do.
65a	11th April, 1917	125	9th August, 1917	140	Do. do.
69a	22nd April, 1917	57	9th August, 1917	210	Do. do.
70a	22nd April, 1917	47	9th August, 1917	210	Close to the basal end a *Marasmius*-diseased spot, about 6 seeds diseased.
71a	22nd April, 1917	21	23rd August, 1917	215	Ripe and healthy.
73a	24th April, 1917	110	9th August, 1917	160	Do. do.
75a	24th April, 1917	60	9th August, 1917	115	Do. do.
77a	24th April, 1917	14	23rd August, 1917	155	Do. do.
78a	24th April, 1917	30	4th August, 1917	175	Fruit ¾ *Marasmius*-diseased.
79a	24th April, 1917	10	3rd September, 1917	165	Ripe and healthy.
83a	26th April, 1917	52	23rd July, 1917	140	Do. do.
84a	26th April, 1917	52	23rd July, 1917	150	Do. do.
86a	28th May, 1917	40	3rd September, 1917	180	Do. do.

Table II.—*Contd.*

Control No.	Marked. Date.	Marked. Length of fruit in mm.	Picked. Date.	Picked. Length of fruit in mm.	Remarks.
109a	12th May, 1917	110	30th July, 1917	145	Ripe and healthy.
111a	12th May, 1917	35	23rd August, 1917	160	Do. do.
144a	12th May, 1917	60	3rd September, 1917	155	Do. do.
117a	14th May, 1917	35	13th September, 1917	155	Do. do.
118a	14th May, 1917	120	23rd July, 1917	160	Do. do.
119a	14th May, 1917	35	4th August, 1917	160	The apical end is totally *Marasmius*-diseased.
120a	14th May, 1917	25	20th September, 1917	180	Ripe and healthy.
122a	15th May, 1917	55	28th August, 1917	145	Do. do.
123a	15th May, 1917	35	13th September, 1917	130	Do. do.
126a	15th May, 1917	55	13th September, 1917	165	Do. do.
130a	16th May, 1917	40	13th September, 1917	130	Do. do.
133a	16th May, 1917	40	13th September, 1917	220	Do. do.
134a	22nd May, 1917	45	15th August, 1917	180	Do. do.
136a	22nd May, 1917	80	15th August, 1917	170	Do. do.
138a	22nd May, 1917	40	13th September, 1917	160	Do. do.
141a	22nd May, 1917	55	13th September, 1917	165	Do. do.
142a	23rd May, 1917	55	28th August, 1917	170	Do. do.
143a	23rd May, 1917	95	13th September, 1917	160	Do. do.
144a	25th May, 1917	55	13th September, 1917	175	Do. do.
145a	25th May, 1917	50	17th October, 1917	155	Do. do.
146a	25th May, 1917	70	12th October, 1917	150	Do. do.
147a	25th May, 1917	45	13th October, 1917	150	Do. do.
148a	25th May, 1917	75	26th September, 1917	155	Do. do.
149a	25th May, 1917	55	28th August, 1917	160	Do. do.
152a	26th May, 1917	75	20th September, 1917	175	Do. do.
153a	26th May, 1917	85	20th September, ...	175	Do. do.
155a	26th May, 1917	95	20th September, 1917	175	Do. do.
156a	26th May, 1917	115	28th August, 1917	155	Do. do.

Table III.—Diameter of Marasmius Mushrooms in Mm.

No.	15th Nov., 1917. 11 a.m.	15th Nov., 1917. 7 p.m.	16th Nov., 1917. 8 a.m.	16th Nov., 1917. 8 p.m.	17th Nov., 1917. 8 a.m.	17th Nov., 1917. 8 p.m.	18th Nov., 1917. 6 a.m.	18th Nov., 1917. 6 p.m.	19th Nov., 1917. 7 a.m.	19th Nov., 1917. 5 p.m.	20th Nov., 1917. 7 a.m.	20th Nov., 1917. 9 p.m.
1	4	6 x	7 x	7 x	dead	—	—	—	—	—	—	—
2	2	2 x	3 x	3 x	3 x	dead	—	—	—	—	—	—
3	3	4 x	5 x	7 x	7 x	dead	—	—	—	—	—	—
4	3	3 x	4 x	4 x	4 x	dead	—	—	—	—	—	—
5	2	3 x	5 x	6 x	6 x	dead	—	—	—	—	—	—
6	2	3 x	3 x	4 x	4 x	4 x	dead	—	—	—	—	—
7	2	3 x	4 x	5 x	5 x	5 x	4 x	4 xo	4 o	dead	—	—
8	4	5 x	5 x	6 x	6 x	5 x	5 x	5 xo	5 o	dead	—	—
9	3	5 x	8 x	9 x	9 x	9 x	9 x	8 xo	8 xo	dead	—	—
10	2	3 x	4 x	5 x	5 x	5 x	4 x	4 xo	4 o	dead	—	—
11	2	2 o	dead	—	—	—	—	—	—	—	—	—
12	2	4 o	9 x	12 x	12 x	13 x	13 x	13 xo	13 x	12 o	11	dead
13	2	4 o	8 x	10 x	11 x	12 x	12 x	12 xo	11 x	10 o	dead	—
14	1	2 o	4 x	9 x	9 x	11 x	11 x	11 xo	11 x	11 o	dead	—
15	1	2 o	5 o	8 x	9 x	10 x	10 x	11 xo	10 x	10 o	9 xo	dead
16	2	4 o	7 x	10 x	11 x	12 x	11 xo	11 xo	10 x	9 o	dead	—
17	1	1 o	4 o	5 x	5 x	7 x	6 x	6 xo	6 xo	5 o	dead	—
18	3	5 x	6 x	7 o	6 o	dead	—	—	—	—	—	—
19	1	1 o	3 o	5 o	9 x	13 x	13 x	14 xo	13 x	13 o	13 xo	dead
20	2	4 x	7 x	9 x	9 xo	dead	—	—	—	—	—	—

x=Many spores. xo=Few spores. o=No spores.

MANURIAL EXPERIMENTS WITH SUGAR-CANE.

II.—A Comparison of the Effect of Pen Manure and Single and Double Applications of Sulphate of Ammonia, Nitrate of Soda and Nitrolim on the Yield of First Ratoon Canes.

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[*This paper was read at the Fourth International Congress of Sugar-Cane Technologists held in Porto Rico in March*, 1932.]

I. Introduction.

In the first paper of this series (5) it has been shown that a significant increment in yield of 32 per cent., or nearly 7 long tons to the acre, can be obtained in one year by a single application of 3 cwt. of sulphate of ammonia to first ratoon canes, of the variety B.H. 10/12, growing on a calcareous soil type. In this paper there are recorded the results of a further and more detailed study of the effect of nitrogenous manures on the yield of canes of the same variety and age, but under different soil conditions. The study includes the following main comparisons:—

(1) The effect of *quantity* of nitrogen on yield, *i.e.*, no treatment *versus* single dressings of 30 lb. of nitrogen *versus* double dressings of 60 lb. of nitrogen.
(2) The effect of *quality* of nitrogen on yield, *i.e.*, sulphate of ammonia *versus* nitrate of soda *versus* nitrolim.
(3) The effect of pen manure on yield.

In this experiment the comparative value of quantity and quality of nitrogen is of special interest, for the period of time during which the applied nitrogen was available to the ratoon crop was limited to 8½ months, three of which fell in the dry season.

The treatment with pen manure is admittedly an abnormal one, for it is never applied to ratoon canes in the usual course of events. It was included to obtain preliminary information as to the effect of a complete organic manure upon the ratooning power of the cane. Under the conditions of soil and climate which obtain in Trinidad it is rarely possible to ratoon more than twice 'noble' canes, such as the variety B.H. 10/12, while in certain areas the crop is limited to one ratoon. An extension to three or more ratoons, such as is possible in Hawaii and Cuba, would considerably reduce field expenses.

The experiment was laid out in the form of a 10 × 10 Latin Square. Fisher's "Analysis of Variance" (2) can therefore validly be used in the examination of the yield data.

As three nitrogenous manures, other than pen manure, were compared, three plots in each row and column received an application of 30 lb. of nitrogen, and three an application of 60 lb. of nitrogen. To preserve the symmetry of the comparison a similar number of untreated plots were included. In consequence, the standard error of the differences due to *quantity* (the differences between the mean yields from the plots without nitrogen and those with single and with double dressings) can in each case be based on data for 30 plots.

Replication in this manner of identical treatments within the row and column of a Latin Square tends to complicate the examination of the yield data. For this reason the analysis has been set out in detail in an appendix.

With the exception of pen manure, the same *kind* of nitrogen is applied to each of 20 plots in the square. The experiment may therefore be expected to give a very accurate comparison of the effect of quality of nitrogen on yield as well as that of quantity.

II. Details of the Experiment.

Cane Variety and Age.—B.H. 10/12 first ratoons.

Soil Type. A deteriorated river alluvium, acid in reaction and in poor physical condition. Its characteristic properties have been described elsewhere (4).

Manurial Treatments to the acre.

(1) No treatment	N_0
(2) No treatment	
(3) No treatment	
(4) 30 lb. Nitrogen as Sulphate Ammonia	N_1
(5) 30 lb. Nitrogen as Nitrate of Soda	
(6) 30 lb. Nitrogen as Nitrolim	
(7) 60 lb. of Nitrogen as Sulphate of Ammonia	N_2
(8) 60 lb. of Nitrogen as Nitrate of Soda	
(9) 60 lb. of Nitrogen as Nitrolim	
(10) 10 tons of Pen Manure.	

Time and Mode of Application of Manures.

The sulphate of ammonia, nitrate of soda and nitrolim were applied by hand to the surface of the soil immediately around the cane stool in June, 1928, *i.e.*, in the first month of the wet season, immediately after the very deep cracks which develop in the soil during the dry season had disappeared. Loss of manure down these cracks could attain considerable dimensions. The manures were not covered in. It has been shown in a previous paper (5) that the increment in yield resulting from burying sulphate of ammonia is statistically not significantly greater than that given by a superficial application.

The pen manure, which was prepared from cane trash by the Mauritius method (1), was forked into the soil in July, 1928.

Design of Layout.

A 10×10 Latin Square (*see* plan). There were 100 plots in all, with 30 replicates of the plots without nitrogen, and 10 replicates of each other plot.

Plot Dimensions.

Each plot was 22 feet (the bed width) by 66 feet (1/30 acre).

Age of Canes on Reaping.

The plant canes were reaped early in March, 1928. The ratoon canes were harvested at the end of March, 1929, when 13 months old.

Previous History of Experimental Area.

The canes on all plots received 20 tons of pen manure to the acre as plants in the wet season of 1926. The yield of plant canes was 43.4 tons to the acre.

III. Plan of Experiment with yield data in long tons per acre (less 30 tons).

Treatment numbers are given in brackets.

Rows.	Columns.										Total.
	1	2	3	4	5	6	7	8	9	10	
1	(3) −4.88	(9) −1.13	(2) −1.13	(7) 2.62	(1) −3.38	(8) 3.00	(5) −3.75	(10) −9.75	(6) 2.62	(4) −4.88	−20.66
2	(1) −1.88	(2) 0.00	(8) 8.25	(5) 7.50	(4) 4.12	(6) 0.37	(9) −1.13	(7) 7.87	(3) 0.00	(10) −2.63	22.47
3	(7) 1.87	(3) −4.50	(6) 0.75	(2) 0.37	(9) 4.12	(4) 3.75	(1) −4.13	(5) 3.75	(10) −0.38	(8) 3.75	9.35
4	(6) −1.13	(8) 4.12	(7) 2.62	(1) −4.13	(10) 0.37	(5) 2.25	(2) −1.88	(4) 6.00	(9) 2.25	(3) −4.50	5.97
5	(10) 0.75	(1) −4.88	(5) 2.25	(8) 6.75	(6) −0.75	(3) 0.75	(4) 8.25	(2) −1.50	(7) 3.00	(9) −2.63	11.99
6	(4) 6.37	(6) 1.50	(10) −0.38	(3) −3.38	(5) 5.25	(9) 7.12	(7) 11.25	(8) 9.37	(2) 2.25	(1) −2.63	36,72
7	(8) 4.50	(7) 3.00	(9) 3.00	(10) −2.63	(2) −2.63	(1) −0.75	(3) −1.50	(6) −0.00	(4) 3.75	(5) −0.38	6.36
8	(9) 2.62	(5) 1.50	(4) 7.12	(6) 0.00	(3) −4.88	(7) 7.50	(10) 0.37	(1) −3.00	(8) 10.87	(2) −0.38	21.72
9	(2) −2.25	(4) −3.00	(1) 7.87	(9) 1.12	(7) 3.37	(10) 8.25	(8) 10.50	(3) −1.88	(5) 4.12	(6) −8.25	19.85
10	(5) −0.38	(10) −6.38	(3) −4.50	(4) 0.37	(8) 7.87	(2) −3.75	(6) −0.75	(9) 3.00	(1) −3.38	(7) −2.25	−10.15
Total	5.59	−9.77	25.85	8.59	13.46	28.49	17.23	13.86	25.10	−24.78	103.62

General Mean = 1.0362

MEAN YIELDS.

Treatment.	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Total	....	....	....	31.85	22.11	−5.64	40.85	68.98	18.34	−12.41
		−60.46			48.32			128.17		
Mean	....	....	....	3.185	2.211	−0.564	4.085	6.898	1.834	−1.241
		−2.015			1.611			4.272		

IV. Analysis of Variance.

The analysis of variance is given in full below. The details of the method are set out in an appendix to this paper.

ANALYSIS OF VARIANCE.

Due to	Degrees of Freedom.	Sum of Squares.	Mean Square.	$\frac{1}{2}\log_e$ (Mean Square).
Rows	9	248.2461	27.5829	
Columns	9	252.0884	28.0098	
Treatments :				
Quantity of Nitrogen (N)	2	639.8884	319.9442	2.8842
Quality of Nitrogen	2	168.0531	84.0265	2.2156
Pen Manure	1	15.4008	15.4008	1.3672
Interactions :				
Quantity and Quality of N	2	36.3749	18.1875	1.4503
Error	74	530.6968	7.1716	0.9851
Total	99	1890.7485		

Results of Analysis.

It is now possible to assess the effects of the various treatments (2) (3).

For P=0.05, $n_1=2$, $n_2=74$, $z=0.5738$.

$n_1=1$, $n_2=74$, $z=0.6933$.

For P=0.01, $n_1=2$, $n_2=74$, $z=0.9784$.

The difference due to quantity of nitrogen in this table is 2.8842—0.9851, or 1.8991. That due to quality is 2.2156—0.9851, or 1.2305. The effect of interactions due to quantity and quality is 1.4503—0.9851, or 0.4652. The effect of *amount* of nitrogen, and the difference due to *kind* of nitrogen are therefore definitely significant. The interactions of quantity and quality are statistically not significant.

The effect of pen manure is 1.3672—0.9851, or 0.3821. It is definitely not significant.

V. Final Statement of Results.

QUANTITY OF NITROGEN.

TABLE I.

YIELDS OF SUGAR-CANE IN LONG TONS TO THE ACRE.

1 Quantity of Nitrogen.	2 Sulphate of Ammonia.	3 Nitrate of Soda.	4 Nitrolim.	5 Mean Value.	6 Difference between Means.
N_0 (No N.)		27.99		27.99	3.62
N_1 (30 lb. N.)	33.19	32.21	29.44	31.61	2.66
N_2 (60 lb. N.)	34.09	36.90	31.83	34.27	

The mean yields in column 5 of Table I are each based on the values for 30 plots. The standard error of the difference between any two mean yields is equal to $\sqrt{(7.1716 \times 2)/30}$ or 0.6915 tons. The significant difference for P=0.01 is equal to 0.6915 × 2.6 or 1.78 tons (2). The mean response of 3.62 tons to single dressings of nitrogen, and the *additional* mean response of 2.66 tons given by double dressings, might therefore be due to chance less than once in 100 times.

As the interactions between quality and quantity are not significant, the statistical significance of the response to single and double dressings of the individual manures such as nitrate of soda alone, for example, remains doubtful.

QUALITY OF NITROGEN.

TABLE II.

EFFECT OF QUALITY OF NITROGEN ON YIELDS IN LONG TONS PER ACRE.

Treatment.	Mean Yields from all plots.	Difference between Mean Yields.
(1) Sulphate of Ammonia	33.64	(1) and (2) —0.91
(2) Nitrate of Soda	34.55	(1) and (3) 3.01
(3) Nitrolim	30.63	(2) and (3) 3.92

The mean yields in Table II are based on the values for 20 plots. The standard error of the difference between any two means is equal to $\sqrt{(7.1716 \times 2)/20}$, or 0.8469. The significant difference for P=0.01 is equal to 0.8469×2.6, or 2.20 tons. For P=0.05 it is 0.8469×2 or 1.7 tons. The difference in favour of sulphate of ammonia or nitrate of soda when compared with nitrolim might therefore be due to chance less than once in 100 times. The difference of 0.91 tons in favour of nitrate of soda, when compared with sulphate of ammonia, is statistically not significant.

PEN MANURE.

TABLE III.

EFFECT OF PEN MANURE ON YIELDS OF RATOON CANES IN LONG TONS TO THE ACRE.

No Treatment	Pen Manure 10 tons per acre.	Difference.	Significant Difference.
27.99	28.76	0.77	1.96

The effect of pen manure is definitely not significant.

VI. Discussion and Conclusions.

Comparative Value of Sulphate of Ammonia, Nitrate of Soda and Nitrolim.

There seems little doubt that the superiority of sulphate of ammonia and nitrate of soda to nitrolim, as nitrogenous manures for ratoon canes, is largely due to their greater solubility. Heavy dews alone are sufficient to cause complete disappearance into the soil of the two former manures. On the other hand, when moist, nitrolim clots into lumps which appear to remain unchanged for months on the surface of the soil. This behaviour renders nitrolim definitely unsuitable as a manure for a short term crop, in that it must greatly retard the transformation of the nitrogen into a form available to the plant.

The form of yield curves for the three manures is recorded in Fig. 1. There appears to be a marked tendency for the increment in yield due to sulphate of ammonia to fall off when the dressing exceeds 30 lb. of nitrogen, *i.e.*, the yields appear to lie on a curve of diminishing returns. By contrast, the double dressings of nitrate of soda and nitrolim give increments twice as large as the single dressings, *i.e.*, over the range investigated, the yield curves for these manures approximate to straight lines.

The mean yield of cane to the acre from a single dressing of sulphate of ammonia is 0.98 tons greater than that given by the corresponding dressing of nitrate of soda. This difference is definitely not significant. In the case of double dressings there is a difference of 2.81 tons in favour of the nitrate of soda. Although the statistical significance of an amount of this order, when based on mean yields from 10 plots, is questionable, such a difference might be expected and can readily be explained.

In a separate series of experiments* it has been shown that sulphate of ammonia, if applied to first or second ratoon canes, has a definite residual effect on the yield of the subsequent ratoon crops. The residual increment due to a dressing of 60 lb. of nitrogen has been found to exceed 2 tons of cane to the acre. The difference between this value and 2.81 tons lies well within the range of experimental error.

The form of the yield curve for nitrate of soda, together with the high degree of correspondence which obtains between the increment in yield due to nitrate of soda and sulphate of ammonia, provided that the residual effect of the latter manure is taken into account, suggest that practically the whole of the nitrogen in the double dressing of nitrate of soda is available to the plant within nine months of the time of application, whereas a longer period is needed for all the nitrogen in a double dressing of sulphate of ammonia to become available. On the other hand, when single dressings of nitrogen are used, there appears to be little to choose between the two manures.

PEN MANURE.

An application of 10 tons of pen manure corresponds roughly to a dressing of 100 lb. of nitrogen. Very little immediate gain resulted from this application, which appears to be inferior in immediate effect even to that of a dressing of 30 lb. of nitrogen as nitrolim. In view of the costliness of pen manure, and of the evident tardiness with which the nitrogen it contains becomes available to the plant, it seems doubtful whether it can advantageously be put to use as a manure for ratoon canes.

VII. Summary.

(1) An account is given of a comparison of the effect of pen manure and of single and double dressings of nitrogen (as sulphate of ammonia,

* Details of these experiments will be published in due course.

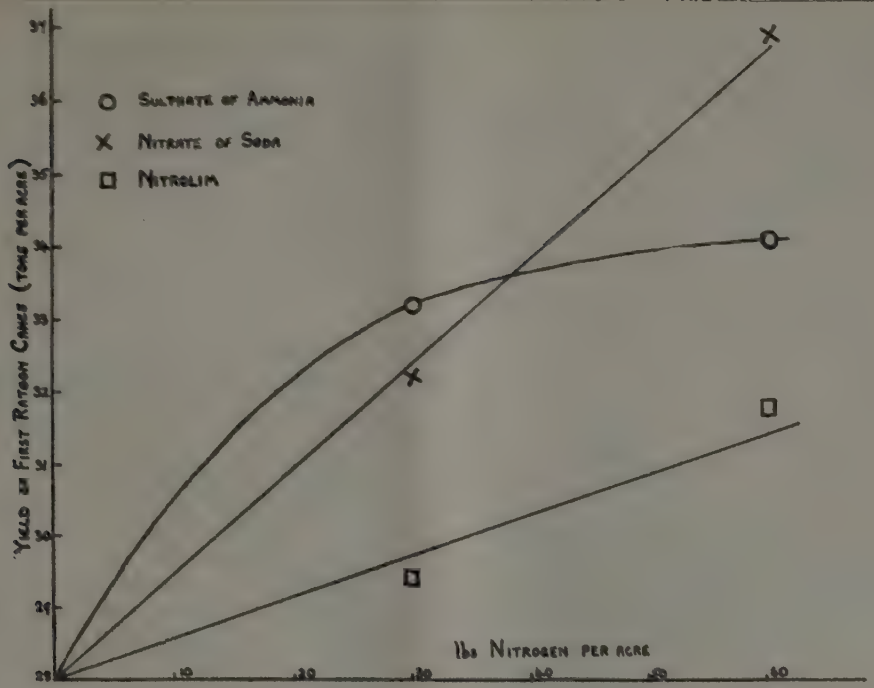

Fig. I-Effect of quantity and quality of nitrogen on yield

nitrate of soda and nitrolim) on the yield of first ratoon canes of the variety B.H. 10/12 growing on a deteriorated alluvial soil type.

(2) The experiment is laid out in the form of a 10×10 Latin Square. The design is such as to lay stress upon the comparison of effect of *quantity* and *quality* of nitrogen on yield.

(3) *Effect of Quantity of Nitrogen.*—It is shown that the mean response of 3.62 long tons of cane to the acre resulting from a dressing of 30 lb. of nitrogen, and the *additional* mean response of 2.66 tons resulting from the dressing of 60 lb. might be due to chance less than once in 100 times.

(4) *Effect of Quality of Nitrogen.*—The mean difference in yield of 3.01 tons of cane to the acre, and of 3.92 tons, in favour of sulphate of ammonia and nitrate of soda, respectively, when compared with nitrolim, might be due to chance less than once in 100 times. The mean difference of 0.91 tons in favour of nitrate of soda, when compared with sulphate of ammonia, is statistically not significant.

(5) The form of the yield curves for sulphate of ammonia, nitrate of soda and nitrolim are recorded. When double dressings of nitrogen are applied, nitrate of soda may possess some advantage over sulphate of ammonia for short term ratoons under the conditions of the experiment. With single dressings there seems little to choose between these two manures.

(6) *Pen Manure.*—The immediate gain derived from the use of 10 tons of this manure is seemingly inferior even to that resulting from a single dressing of nitrolim.

(7) The method of application of Fisher's "Analysis of Variance", to the examination of the yield data obtained from a complex experiment of this nature, is illustrated in an appendix to this paper.

Acknowledgment.

The author is indebted to Mr. G. B. Westwood, of the Ste. Madeleine Sugar Co., Ltd., Trinidad, for permission to publish the data recorded on p. 178, and to Mr. G. A. Jones to whom the success of the experiment is largely due.

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(3) Fisher, R. A., and Wishart, J. (1930). The arrangement of field experiments and the statistical reduction of the results. *Tech. Communication* No. 10, Imperial Bureau of Soil Science, Rothamsted.

(4) Turner, P. E. (1929). Liming as a factor in the amelioration of deteriorated tropical soils. *Journal of Agricultural Science* XIX, 83.

(5) Turner, P. E. (1932). Manurial experiments with sugar-cane. I. Burying *v* non-burying of sulphate of ammonia in relation to its effect on the yield of first ratoon canes. *Tropical Agriculture*, Vol. IX, No. 5, p. 153.

Appendix.

ANALYSIS OF YIELD DATA.

There are 100 plots in all, and therefore 99 degrees of freedom. If the untreated plots ((1) (2) and (3)) are regarded as receiving distinct treatments the analysis would be :—

Due to	Degrees of Freedom.	
Rows	10−1 =	9
Columns	10−1 =	9
Treatments	10−1 =	9
Error	9×(9−1) =	72
Total		99

As there are only 8 distinct treatments, the number of degrees of freedom for treatments is 7. The variation between the 27 untreated plots, with 9 × (3-1), or 18, degrees of freedom, is properly ascribed to error, since it is the variation, within rows or columns, of similarly treated plots.

The analysis therefore becomes :—

Due to	Degrees of Freedom.	
Rows		9
Columns		9
Treatments		7
Error	7×(9−1)=56 9×(3−1)=18	74
Total		99

The 7 degrees of freedom for treatments may be further subdivided into effects respectively due to :—

(*a*) quantity of nitrogen (2),
(*b*) quality of nitrogen (2),
(*c*) interaction of quantity and quality of nitrogen (2), and
(*d*) pen manure (1).

The details of the subdivision are given in the arithmetical working which follows. They correspond to the method used by Fisher and Wishart (3) in the analysis of a layout in the form of randomised blocks.

ROWS AND COLUMNS.

Rows.		Columns.	
Number.	Square.	Number.	Square.
(1) −20.66	426.8356	(1) 5.59	31.2481
(2) 22.47	504.9009	(2) −9.77	95.4529
(3) 9.35	87.4225	(3) 25.85	668.2225
(4) 5.97	35.6409	(4) 8.59	73.7881
(5) 11.99	143.7601	(5) 13.46	181.1716
(6) 36.72	1348.3584	(6) 28.49	811.6801
(7) 6.36	40.4496	(7) 17.23	296.8729
(8) 21.72	471.7584	(8) 13.86	192.0996
(9) 19.85	394.0225	(9) 25.10	630.0100
(10) −10.15	103.0225	(10) −24.78	614.0484
Total	3556.1714	Total	3594.5942
Divide by 10	355.6171		359.4594
Subtract	107.3710		107.3710
Remainder	248.2461		252.0884

GENERAL ANALYSIS.

The sum of squares of the 100 plot yields (taken from an arbitrary mean of 30) is 1998.1194. To correct for the arbitrary mean, there is subtracted 107.3710 (which is 1/100 of the square of the grand total of 103.62). The difference is 1890.7484. From this total the sums of squares due to rows, columns and treatments are subtracted.

ROWS AND COLUMNS.

Treatments.

The first number is the total of 30 plots. The others are totals of 10 plots. The calculation is therefore as follows:

Number.	Square.
−60.46	3655.4116
Divide by 3	1218.4705
31.85	1014.4225
22.11	488.8521
−5.64	31.8096
40.85	1668.7225
68.98	4758.2404
18.34	336.3556
−12.41	154.0081
Total	9670.8813
Divide by 10	967.0881
Subtract	107.3710
Remainder	859.7171

The sum of squares due to error is ascertained by subtraction.

Due to	Degrees of Freedom	Sum of Squares.
Rows	9	248.2461
Columns	9	252.0884
Treatments	7	859.7171
Error	74	530.6968
Total	99	1890.7484

DETAILED ANALYSIS.

The components into which the sum of squares due to treatment can be divided, in order to ascertain the separate effects due to the particular manures tested, are now taken in order.

(*i*) *Quantitative Effect of Nitrogen.*

The following table is formed from the lower margin of the table yields. Each figure is the total for 30 plots.

No Nitrogen.	Single Nitrogen.	Double Nitrogen.
−60.46	48.32	128.17

Number.	Square.
−60.46	3655.4116
48.32	2334.8224
128.17	16427.5489
Total	22417.7829
Divide by 30	747.2594
Subtract	107.3710
Sum of squares due to quantity of N. (*a*)	639.8884
	(2 degrees of freedom)

(*ii*) *Qualitative Effect of Nitrogen and Interaction with Quantity.*

The table overleaf is constructed from the lower margin of the yield table, the data for the untreated plots being omitted.

The result (*b*) is the sum of squares due to qualitative differences in the nitrogen applied; (*e*) represents the difference between single and double nitrogen, and is included in the amount (*a*); (*c*) represents the interaction between quality and quantity of nitrogen.

(*iii*) *Pen Manure.*

Number.	Square.
−12.41	.... 154.0081
Divide by 10 (d)	.... 15.4008 (sum of squares due to effect of pen manure.)

The sum of squares due to the effect of pen manure (d) could have been obtained by subtraction from the treatment total of 859.7171, for all the other items have been determined.

It is now possible to present the completed analysis of variance.

ANALYSIS OF VARIANCE.

Due to	Degrees of Freedom.	Sum of Squares.
Rows	9	248.2461
Columns	9	252.0884
Treatments:		
Quantity of Nitrogen (N)	2	639.8884
Quality of Nitrogen	2	168.0531
Pen Manure	1	15.4008
Interactions:		
Quantity and Quality of N.	2	36.3749
Error	74	530.6968
Total	99	1890.7485

Quantity.	Quality.			Total.
	Sulphate of Ammonia.	Nitrate of Soda.	Nitrolim.	
(1) 30 lb. N.	31.85	22.11	−5.64	48.32
(2) 60 lb. N.	40.85	69.98	18.34	128.17
Total	72.70	91.09	12.70	176.49

Number.	Square.	Number.	Square.
31.85	1014.4225	72.70	5285.2900
22.11	488.8521	91.09	8297.3881
− 5.64	31.8096	12.70	161.2900
40.85	1668.7225		13743.9681
68.98	4758.2404	Divide by 20	687.1984
18.34	336.3556	Subtract	519.1453
	8298.4027	Remainder (b)	168.0531†
Divide by 10	829.8403	$(128.17 - 48.32)^2$	6376.0225
$(176.49)^2 \div 60$	519.1453	Divide by 60 (c)	106.2670‡
Difference	310.6950*		
Subtract	168.0531		
and	106.2670		
Remainder (c)	36.3749†		

* 5 degrees of freedom. † 2 degrees of freedom. ‡ 1 degree of freedom.

AGRICULTURE IN CEYLON.*

THE first section of this report is devoted to a summary of the agricultural position at the end of the year and the progress achieved by the Department during the 12 months under consideration. This summary is written by the Director of Agriculture and gives a brief but clear account of the very depressed condition of all branches of agriculture in the Island. The exports in practically all the crops, both major and minor, show a distinct decrease as compared with the previous year's figures: in addition, the selling price per unit is generally much lower. For example, the decrease during the year in the value of 1 cwt. of cocoa was approximately 40 per cent. The main reason for the somewhat unhappy agricultural situation is, of course, the world-wide economic depression.

The remainder of the publication is made up of the reports of the heads of the various sub-divisions of the Department. The reader is bound to be impressed by the extraordinary number of different crops that are produced commercially, and in many cases, produced on a relatively large scale. Ceylon is obviously a veritable tropical garden, and the experimental work and activities of the Department are on a correspondingly varied scale. Reports of the type under review are consequently of general interest to farmers and planters with land in the tropics.

It is pleasing to note that the problem of soil erosion is being tackled in a really effective manner. The findings of a Committee appointed by the Ceylon Government to investigate this question are embodied in a separate report. This Committee's suggestions are being tried out in practice, and whether or not the methods employed prove effective, the results should be very instructive and useful to other Colonies with similar climatic conditions.

D. D. P.

* Administration Report of the Director of Agriculture of Ceylon for 1930. *Ceylon Government Press*, Colombo.

THE CACAO INDUSTRY OF TRINIDAD.

SOME ECONOMIC ASPECTS.

Part III.—History of the Industry up to 1870.

By C. Y. Shephard.

The exact date of introduction of the cacao tree into Trinidad is unknown, but there is no evidence to indicate that, "from its first settlement, Trinidad exported cacao" (3). The fact that the Spaniards reported "the discovery" of the tree in the island in 1617, suggests that it had not been widely cultivated up to that time, and it was not until the beginning of the eighteenth century that cacao first became, for a brief period, the staple product of Trinidad. Indeed the first Spaniards to explore the New World were disinterested in all forms of agriculture; they came in a spirit of adventure, infused with the hope of discovering treasure. They soon exhausted the accumulated stores of the Indians, particularly of Mexico and Peru, and then enslaved the inhabitants of the larger islands and the Main, for exploiting the gold and silver mines, and the pearl fisheries. Trinidad successfully resisted conquest, but was raided for slaves to work the pearl grounds of Cabagua and Margarita (15). This phase was terminated in the middle of the sixteenth century, by the "New Laws for the Indies", which re-established the fundamental principle, of 1512, that Indians were free men, and again rejected the presumption that they were incapable of Christian salvation, and thereby fit only for slavery (13). A special officer, the Licenciado, was sent in 1548, to stop the slave traffic in Venezuela, the Pearl Coast, and Trinidad (13).

Each Conquistador, or Adelantado,* engaged in exploration and conquest, had always been assigned two specific tasks: the reduction, conversion, and preservation of the Indians, and the founding of Spanish towns (25). In Trinidad, this period dates from 1591, when Antonio de Berrio, profiting by the violent conflicts of the Arawaks and Caribs, established a permanent government at St. Joseph † (14). In common with the other parts of the Spanish colonial empire, the administrative system included the "encomienda" (13), *i.e.*, the grant of Indian settlements to the Spaniards, who were required to protect the Indians, and provide Christian instruction, in return for a fixed tribute, or task of labour. This system was the basis of the first agricultural development in Spanish times, and led to the establishment of a tobacco industry in Trinidad. In the early part of the seventeenth century English and Dutch ships called frequently at Trinidad to trade in tobacco, the quality of which earned eulogistic references from contemporary English writers, but there was still no trade in cacao.

The trade in tobacco with foreign ships and towns was contrary to the rigid system which restricted the trade of Spanish colonies to Spanish vessels, and to Spanish ports. But Spanish ships seldom visited Trinidad, and throughout the seventeenth century complaints of the absence of registered Spanish ships were frequently sent to the King (3). Moreover, as the Spanish ships were more liable to capture, their freight charges were seven to eight times as great as the Dutch and English ships (23). In 1611 a special commissioner was despatched to Trinidad to deal with the contraband trade, as a result of which the inhabitants were reprimanded and the Governor dismissed (1). As the contraband trade decreased, tobacco cultivation in the island diminished. In addition, the French, English and Dutch, at the beginning of the seventeenth century, began to effect settlements in the islands, and on the mainland, and these were used as bases for attacks on Spanish ships and colonies. Between 1594 and 1674 Trinidad suffered five serious, and many minor, raids, which further handicapped its development. Furthermore, the growth of tobacco exports from other islands depressed prices so seriously that successful competition by Trinidad was rendered even more remote.

Faced with these difficulties the Spaniards in Trinidad gave serious attention to the cultivation of cacao, which had not been introduced into the neighbouring foreign settlements, and therefore offered greater prospects of a remunerative market. Cacao plants were imported from Venezuela, then another Spanish colony, about 1678 (2), and the small but lucrative industry which was established soon gave rise to demands for additional labour. In the meantime the "encomiendas" were gradually being withdrawn all over the Spanish colonial empire, and the control of the Indians was being entrusted to missionary priests. It was not until 1687 that such missions were established in Trinidad (32). Immediately the Indians were collected into

* Governor of a province.

† Joseph (15), the historian, believed that the Caribs did not inhabit Trinidad, for they were such bitter enemies of the Arawaks that he considered both could never have resided in the same island. Dr. Wise, the leading authority on the history of Trinidad under Spanish rule, states that Caribs were present in considerable numbers in the North, at St. Joseph, Caura, Tacarigua, Arouca, Arima, and Manzanilla, between 1580 and 1800 while the Arawaks were found to the South of the Montserrat Hills.

these centres, the Spaniards demanded, and were granted, permission to send them as labourers into the cacao fields, in return for pay, food and instruction in Christianity. The planters disregarded their obligations, and, after periods of six or eight months, the Indians returned to the missions exhausted, sick with hunger, untaught and unpaid. The missionaries refused to continue the arrangement, and, although they were supported by the Governor, they were compelled to leave the island, by the Royal Cedula* of 1708, and to hand over the missions to the regular clergy (29). The planters' victory was an empty one, for the Indians promptly deserted the missions, and took to the mountains (8).

At the beginning of the eighteenth century, therefore, the estate owners began to rely upon negro slaves.† The "Asiento de Negros", which was awarded to the French Guinea Company in 1701 (15), and the English South Sea Company in 1713, enabled the planters to obtain slaves with greater regularity and ease. Cacao had become the staple product of the island, and, as it was considered superior in quality to cacao from Caracas and other places, it was readily bought, and paid for, in advance. The colony was now enjoying unprecedented prosperity, for cacao sold at an extremely high price. But the happiness of the planters was short-lived, for the industry was destroyed by a "blast" in 1727, and, as cacao was the sole article of export, the commerce of the island was immediately crippled, and ruin soon followed (34). The starving colonists and their slaves sought refuge on the mainland, while the native Indians turned to the cultivation of cassava, maize, and tobacco (15). By 1733 the adult male population, exclusive of Indians, had dwindled to 162, of whom only 28 were white.

The nature of the "blast" can only be conjectured. Gumilla proclaimed it an Act of God, inflicted as a punishment of those planters who had not paid their tithes. His argument was supported by the fact that Rabelo (?Robles), a planter who invariably paid his tithe, suffered no damage (5). Tradition affirms that Rabelo's cacao was of the Forastero variety, which was inferior in quality and could not be sold in advance, and made it difficult for him to evade his tithe. Further, the hardier nature of these trees enabled them to withstand the "blast". Others ascribed the failure of the industry to the north winds, to a prolonged drought, or even to the appearance of a comet (15). More recently Sir Daniel Morris interpreted the word "blast", as "blow" or "hurricane" but, as Trinidad lies outside the hurricane zone, this is unlikely to be the true explanation. Hart explained the term to mean "blight" (12), while Nowell expressed the opinion that the failure was probably due to pod rot, and stem canker, caused by the fungus *Phytophthora palmivora* (22). This conforms with Gumilla's description "that the trees were apparently healthy and vigorous; the flowering abundant, giving fruits; but none of them came to maturity, as the young pods dried up before full fruits" (34). Whatever the cause there is no question of the effect.

The industry was revived by the introduction of the hardier Forastero variety of cacao in 1756*. The new variety proved far hardier, and for more than a hundred years no disease of economic significance was reported (12). The industry was being re-established at an extremely slow rate, and, in order to stimulate more rapid progress, the trade of the island was thrown open to foreigners by a Royal Decree of 1765 (5). This concession provoked little response, and even in 1780 commerce was confined to a little cacao, vanilla, indigo, anatto, cotton and maize, which were bartered for coarse cloth and implements. Two or three visits annually by a Dutch vessel of 150 tons were sufficient for the entire trade of Trinidad (17).

During 1777 a Frenchman from Grenada, M. Roume de St. Laurent, visited Trinidad and was most favourably impressed with its agricultural potentialities. While visiting Caracas on other business, he persuaded the Intendant to publish a Cedula (in 1780 or 1781) offering special favours to immigrants. A number of French, and a few Irish colonists, were induced to settle in the island. Laurent, however, pursued his negotiations in Madrid, and secured far more favourable terms, which were embodied in the famous Cedula of 1783. Don Chacon, was appointed Governor to see these generous regulations enforced, and he interpreted them in a very liberal manner. The sole restrictions were, that immigrants were required to profess themselves Roman Catholics, and to take an oath of allegiance to the King of Spain. The primary inducement was the grant of 32 acres of land for each member, of either sex, of a white family, and an additional 16 acres for every slave. Free negroes and people of colour were allowed 16 acres for each free person, and eight acres for each slave. These settlers were entitled to bring their belongings into the Colony free of duty, and were also exempted from taxation for a period of ten years. Cattle, horses and mules were imported from Caracas, and agricultural implements from Spain, and sold to the immigrants at cost price. Trade with the French West Indian Islands was

* Decree.

† A Dutch merchant had delivered a special shipment of 470 negroes, to rebuild the destroyed settlements at St. Joseph, as early as 1606 (24). There is no record of any further importation until the demands of the cacao industry exceeded the supply of labour obtainable from the native tribes.

* The credit for this importation is usually ascribed to the Aragonese Capuchin Fathers, who had resumed mission work in Trinidad in 1722, though Borde suggests that the Dutch, who were carrying on a small clandestine traffic with the island, may have been responsible (4).

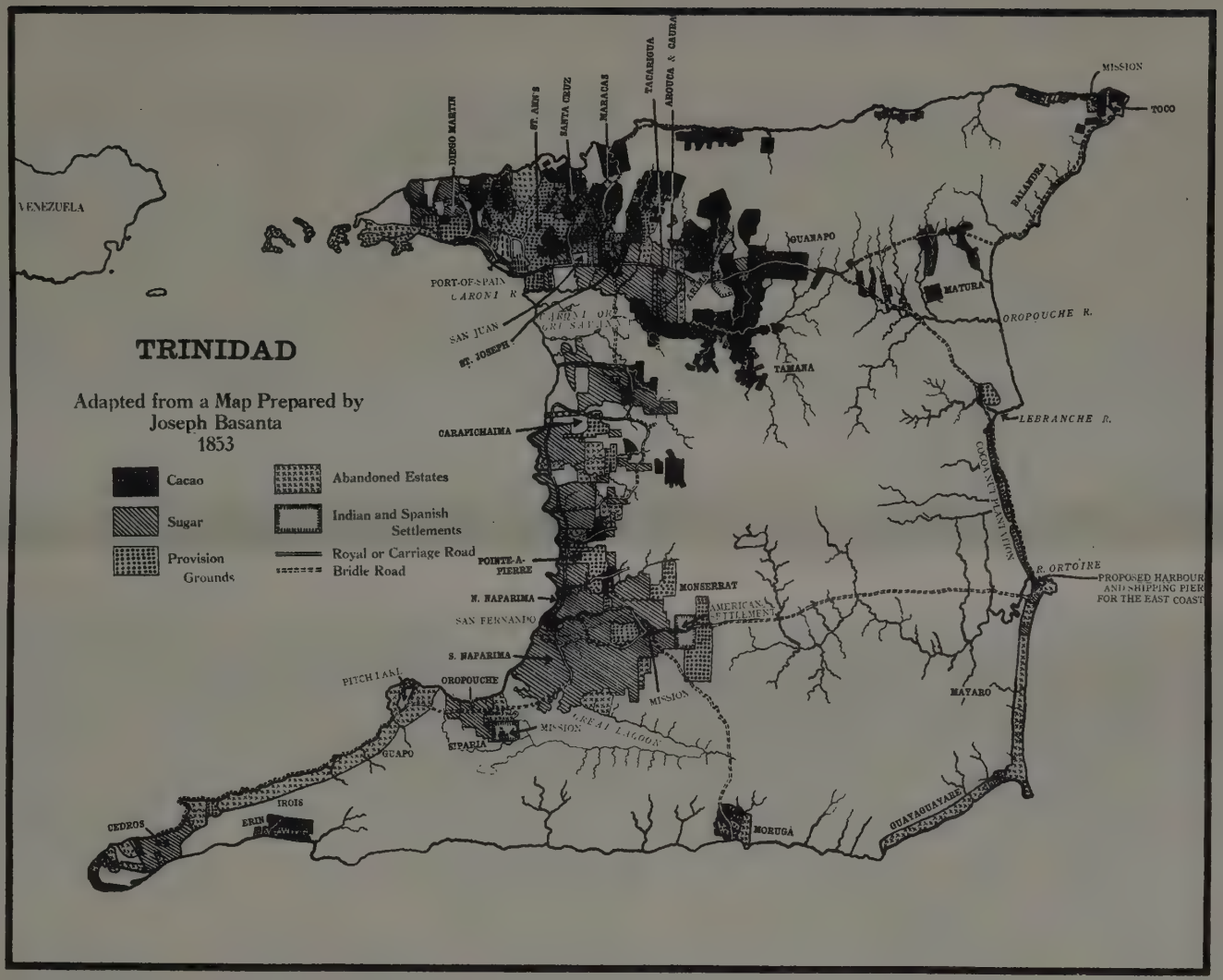

FIG. V.—*The original map was prepared by Joseph Basanta, Surveyor General, to illustrate the Report on "The Condition of the Sugar Growing Colonies", which was laid before the House of Commons in* 1849. *The "abandoned" areas formerly consisted primarily of sugar-cane estates which succumbed as the result of the emancipation of the slaves, and the removal of the preference on British-grown sugar in* 1846. *It will be observed that the principal areas under cacao were confined to the Western part of the Northern Range, and the 'vegas' of the Caroni River.*

permitted under specially favourable conditions. The Governor appears to have exempted the new colonists from responsibility for any debts previously contracted in foreign countries, though the Cedula conferred no such authority.

This Cedula gave the first real impetus to the development of the Colony. The results were immediately reflected in the statistics of population. It was noted that the adult male population, exclusive of Indians, had dwindled to 162 in 1733. In spite of the offers contained in the Cedula of 1780 (or 1781) the total population had risen to only 2,813 in 1782, and of these 2,082 were Indians. Six years after the publication of the Cedula of 1783, however, the population was seven times as great, numbering 18,918 of whom 10,100 were slaves, 2,200 Indians, 4,467 free coloured people, and 2,151 whites. Most of the new settlers came from Grenada, which had been in French occupation between 1779 and 1783, but had reverted to the British by the Treaty of Versailles. Others came from Cayenne, Martinique and Guadeloupe. Though still a Spanish Colony, Trinidad was not only occupied by the French, but also governed principally by their advice, for in 1786 the Cabildo* of Port-of-Spain comprised no fewer than seven Frenchmen, only two Spaniards, and one Irishman (10).

These inducements attracted many good settlers, but some were of an undesirable character. Each immigrant sought to bring with him, or to import, as many slaves as possible, on account of the additional land which he could thereby acquire. Some planters are alleged to have kidnapped slaves, or even individuals whose appearance might enable them to be passed as slaves. Slaves who were deported from other islands on account of their criminal tendencies were welcomed in Trinidad. Many rogues and debtors found Trinidad a safe and welcome sanctuary. A contemporary law of Grenada described Trinidad as "a retreat for fraudulent debtors and stealers of slaves, and where no redress or justice may be had" (15). Don Christoval de Robles, a public officer of long service in Trinidad, averred that, "the population is mostly composed of refugees and desperate characters, who have been implicated in all the rebellions and massacres in the neighbouring islands. Their principles are incompatible with all regular government" (15). Both authorities were prejudiced, for the one came from a British source, and the other from a member of the Spanish nobility, neither of which then entertained a favourable opinion of the French. Nevertheless the presence of an unruly section in the community caused the administration a great deal of anxiety, and clashes between the French privateers and British sailors are alleged to have precipitated Spain into the war which resulted in the capture of Trinidad by the British.

* Corporation.

The new settlers, instead of assisting the development of the cacao industry, concentrated upon the sugar industry, with which they were already familiar. Though the Spaniards introduced the sugar cane to the New World they never became identified with the sugar industry in Trinidad. Hitherto the island had produced only an inferior quality of sugar, called *papelones*, in quantities barely sufficient to meet the requirements of the inhabitants (15). Sugar became the staple product of Trinidad by 1793, and remained so for more than a century. The location of the "usines" was dictated primarily by considerations of transport. Roads capable of carrying wheeled traffic were practically non-existent. The sugar estates were concentrated, therefore, along the flat shores of the sheltered Gulf of Paria, which afforded easy shipment both to Port-of-Spain and overseas. A few "usines" were located at suitable points on the eastern and southern coasts (15). Cacao, being less bulky, was not so restricted in location, but most of the estates were scattered along the foot-hills and valleys of the Northern Range, and the "vegas"* of the Caroni River, which afforded easy access to Port-of-Spain by bridle path. The interior of the island remained completely undeveloped; in fact, the only closely settled districts were the sugar areas of North and South Naparima (7).

The sugar industry had barely been firmly established when war broke out again between England and Spain, and Trinidad was captured, with little effort, by a powerful English expedition in 1797. The stream of settlers into Trinidad, following the Cedula of 1783, had become exhausted by 1789, and there was little change in the population until 1797, when the departure of those who refused to take the oath of allegiance to the King of Great Britain, reduced the total population to 17,643. When Trinidad was acquired the sugar industry in other British possessions was enjoying exceptional prosperity. Revolution in Santo Domingo had reduced the world's supply of sugar by more than 50,000 tons, and the outbreak of war between France and Great Britain, in 1793, had cut off the remaining supplies of French sugar. The price of sugar in England rose from 32*s*. a cwt., in 1793, to 87*s*. a cwt., in 1798 (30), and feverish efforts were made to increase the production of British grown sugar. By 1803, the total population of Trinidad had risen to 31,000 chiefly by reason of the addition of 11,000 slaves, who now numbered 21,000 (10).

The energies of the new immigrants were devoted almost exclusively to the profitable sugar industry, and between 1797 and 1802 the output of sugar rose from 7,800 hogsheads to

* The word "vega" is used in Trinidad to denote a tract of level land bordering a river.

15,461 hogsheads* (34). But sugar prices fell as rapidly as they had risen. The market collapsed in the middle of 1799, and during 1,800 and 1801 the highest price was 50*s.* a cwt., and the lowest only 28*s.* a cwt. For some years the production of sugar in Trinidad showed little expansion, but cacao, the most important minor crop, made small but definite progress, the production rising from 96,000lb.† in 1797 (or 1796) (10, 34) to 361,070 lb. in 1803 (10).

By the Treaty of Amiens, Trinidad was definitely ceded to Great Britain, and a number of Scotch and English adventurers came to the island from the foreign colonies, which had temporarily been in British occupation. These immigrants were incensed to find the principal posts of trust filled by British Roman Catholics (20), or by foreigners. Thus Picton's Council of Advice consisted of three Irishmen, one Frenchman, and one Spaniard (18). The Governor's impartial attitude towards the various European nationalities caused many of these British settlers to leave the island, with the result that by 1806 the population had increased to only 31,133. Nevertheless large areas of land had already been cleared, and with the importation of additional slaves, the production of both sugar and cacao could have been expanded. But in 1807 the slave trade was abolished. The planters then introduced slaves from the more thickly populated neighbouring islands, but in 1824 this, too, was prohibited (10). This restriction was severely felt by the newly developed industries of Trinidad, for there was only one slave to every seven acres occupied, compared with a slave for every acre of cultivation in the older British West Indian islands. The planters exacted longer hours of work, and curtailed the number of "free-days" from 134 to 69 per annum, in order to augment their supply of labour (19). The exports of cacao rose from 355,000 lb. in 1807, to 1,214,093 lb. in 1821, but the production of sugar, which had reached 18,000 hogsheads in 1807, rose only to 20,000 hogsheads in 1821 (7).

An enquiry into the validity of certain land titles increased the difficulties of the planters.‡ Some grants of land had been made prior to 1783; many under the Cedula of that year; others during the British occupation between 1797 and 1803; and, finally, others after the island had definitely become a British colony. Many planters lacked documentary proof of ownership, and the confusion was further complicated by the sale of land for which no valid title existed. By a Proclamation of December, 1815, the Governor required that each planter should, at the least, maintain one-fourth of his land in cultivation, and one labourer for every five quarrées of land (10, 15). Any owner not complying with these regulations was required to pay an annual quit rent of five shillings currency per quarrée, or in default, to suffer confiscation of his land. Those who acquired land under certain conditions and restrictions which had not been observed, were entitled to claim only the portion actually in cultivation, on payment of a fine of £100 currency, and an annual quit rent of five shillings per quarrée (31). The planters complained that the abolition of the slave trade made it impossible for them to observe their obligations, and, as their ownership was called into question, they found it extremely difficult to obtain credit. Only after much litigation, and the visit of a Commission from England in 1824, was the land question settled to the satisfaction of the planters, and a measure of confidence restored (15).

During this period the cacao industry was buoyed up by a period of high prices. The struggle of the Spanish colonies for independence severely curtailed the supply of cacao, the value of which soared, at one time, to as much as $28.00 (116*s. d.*) a fanega, and sold for several years at the profitable level of $14.00 (58*s.* 4*d.*) to $16.00 (66*s.* 8*d.*) a fanega. The exports of cacao from Trinidad rose, from less than 300,000 lb. at the beginning of the century, to 3,700,000 lb. in 1827. By that time, however, both old and new sources of supply had been stimulated to such an extent that prices fell to as low as $3.00 (12*s.* 6*d.*) a fanega. So many planters refrained from picking their cacao, because the attendant expenses rendered it unprofitable, that the exports fell to 1,300,000 in 1830 (34). It was not until the forties that the exports of cacao again regularly exceeded 3,000,000 lb.

Both the cacao and sugar planters were soon confronted with new labour problems. Despite the introduction of task work, and other measures for the amelioration of slavery, the planters began to lose control of their labourers. When the apprenticeship system was introduced on 31st August, 1834, many of the labourers refused to work, for they were unable to appreciate the difference between apprenticeship and freedom, or the distinction between praedial and non-praedial apprenticeship. The ring-leaders were punished, and order was restored, but passive resistance continued, and the exports of both sugar and cacao diminished. On 1st August, 1838, all apprentices were completely emancipated, but, unfortunately, little use had been made of the respite, afforded by the apprenticeship system, to prepare the negroes for the responsibilities of freedom. They exhibited a strong aversion to field work on the estates, and either flocked to the towns and villages, with the intention of becoming

* Two other authorities give the exports as (*i*) 26,728 cwt. in 1799 and 69,551 cwt. in 1801 and (*ii*) 8,500,000 lb. in 1799 and 16,000,000 in 1803. According to de Verteuil, the hogshead quoted was equivalent to 1,600 lb.

† This amount was probably the production of a limited number of estates, and not of the whole industry.

‡ Chacon had experienced great opposition to his attempt to prevent the development of swollen and indefinite estates, and to keep areas open for new settlers. In 1785, by a proclamation similar to that of 1815, he attempted to solve the complicated problem of land titles, but met with little success.

artisans and petty traders, or squatted upon Crown Lands. The planters secured an Order in Council, of 1838, which was designed to compel the negroes to return to the estates, by making the legitimate acquisition of small-holdings practically impossible (7). By this means Government hindered the development of both the cane-farming and peasant cacao industries. But as the Commandants of Quarters formerly granted permits for the occupation of Crown Lands, without specifying the boundaries, it became extremely difficult to distinguish unauthorised squatters from legitimate occupiers. Squatting increased in consequence, and, as will be shown in the next article, it was the solution of this problem which greatly facilitated the development of the cacao industry.

The slave owners in Trinidad received £1,039,000 in compensation, which was used largely in liquidating mortgages and other indebtedness. Frantic efforts were now made to remedy the shortage of labour by "voluntary immigration" from a wide variety of sources. Since the solution of this problem was largely responsible for the rapid development of the cacao industry, at a later date, the negotiations may be followed in some detail. A few Chinese had been introduced as early as 1806, but the experiment proved a complete failure (15). Some 4,000 Africans, captured and liberated from foreign slave traders, by the British squadron off the Guinea coast, were landed in Trinidad (10). A few immigrants from Madeira and Brazil arrived in 1835, but they proved such easy victims of disease that this uncontrolled experiment was discontinued (9). Trinidad followed the example of Mauritius by recruiting a few East Indians in 1838, but the alleged abuses of this "new species of slave trade" led to its speedy termination by the Government of India (35). Labourers were attracted from the other West Indian Islands (7), the United States of America, Malta and Germany (6), by the high rates of wages, the expenses of their introduction being borne by the Colonial Treasury. These immigrants were of little use, for the negroes immediately associated themselves with the emancipated slaves, and the whites proved incapable of working continuously under tropical conditions. Recruitment from these sources was terminated by an Order in Council of 1838, which declared invalid, any labour contract, exceeding one month, executed outside the colony (6). Despite these various efforts to secure immigrants the population of the island actually diminished from 41,120 in 1824 to 39,328 in 1838. The exports of sugar, which had averaged 23,000 hogsheads during the 'thirties, fell to 17,000 hogsheads in 1840, while cacao had barely recovered to the level of the 'twenties (28).

The authorities were still determined to solve the labour problem "by the immigration of a fresh labouring population to such an extent as to create competition for employment". Africans were imported from the Kroo coast in 1841, but the system was so carefully hedged with safe-guards, that few were obtained after the first two years. The West India Committee petitioned for the recruitment of contract labourers from Africa, India and China, and, after prolonged negotiations, licences were actually issued for the introduction of Chinese coolies into Trinidad (9). The immediate need for these immigrants was removed when permission was obtained to recruit Indian labourers, under Government control, for periods of not less than three years. The first of these labourers arrived in 1845, and, as arrangements were made to supplement this supply from Madeira, it appeared that the labour difficulties of the planters would soon disappear.

A further and more serious crisis immediately developed. The emancipation of the slaves in the British colonies resulted in increased costs of production of both sugar and cacao. A substantial preference in favour of the British producers had enabled them to compete with those foreign countries in which slavery was still maintained. But "Free Trade" followed hard on the heels of emancipation, and by the Sugar Act of 1846 (26), the preference on British sugar was removed, and in 1853 British cacao suffered a similar fate. The planters maintained that without an abundant supply of cheap labour they would be unable to maintain their estates. Unfortunately the East Indian immigrants of 1845 had been recruited from the city streets and bazaars, and were unaccustomed to agricultural work. The promises of the recruiters had proved false, and many of them wandered about the country, begging or stealing as the opportunity arose, and working only when compelled by necessity.

It was soon appreciated that East Indian immigration would inevitably fail unless elaborate precautions were introduced into the system. Therefore, in 1847 and 1848, Ordinances were introduced in Trinidad to define the mutual obligations of employer and employee regarding medical attention, the period of indenture, the obligation to work, and the right to a return passage. These amendments proved belated, for the Anti-Slavery Society had so strenuously urged objections to the disciplinary methods of the estates, that recruitment was stopped during 1849 and 1850. In the meantime the Africans, who had been introduced in 1841, were insisting upon their right of repatriation. A frightful famine in Madeira caused the exodus of large numbers of labourers to the West Indies and British Guiana, but they were so debilitated by privation, and so unaccustomed to the climate, that many rapidly succumbed, while others became petty traders. In desperation the planters again turned to the Far East where the impoverishment of Southern China was causing extensive emigration. Private traders obtained permission to recruit coolies under a Bounty System, and, in 1850, some 990 were landed in Trinidad (9). Difficulties immediately arose on account of the absence of female emigrants, the language bar,

and the aversion to European medical methods. Moreover, the abuses of speculative competition between the various European nations in China for coolies threatened to interfere seriously with general commerce. It was decided, therefore, to confine recruitment to Government agencies, but such formidable obstacles arose that Chinese emigration was discontinued until 1859. Again the outlook appeared hopeless.

In the meantime negotiations had been continued for the resumption of East Indian immigration, and, by 1851, satisfactory arrangements were concluded with the Indian Government. The labourers were to be recruited, and allocated to individual estates, by Government officials. The mutual obligations regarding housing, wages, work, discipline, medical attention, and repatriation were more clearly defined. The interests of the labourers were safeguarded by the appointment of a Government official, termed the Protector of Immigrants. At last the problem of securing an adequate, cheap, and amenable supply of labour had been solved. The planters could obtain as many labourers as they required, by the simple process of paying certain fees, and observing the regulations of the Immigration Ordinance. Interest in alternative sources of labour immediately subsided, and a steady stream of East Indian indentured immigrants flowed into Trinidad up to 1917. Between 1843 and 1875 some 84,731 immigrants were introduced into the island, of whom 68,662 were East Indians, 2,645 Chinese, 6,375 Africans, 6,105 West Indians, while the remainder came from a wide variety of countries (18).

With the aid of indentured labour the production of sugar showed a steady expansion, and the exports reached 51,000 hogsheads in 1869. During the 'sixties sugar production had become highly profitable, and there appeared no immediate limit to the expansion of the industry. Cacao, too, had shown considerable development, and, in 1869, exports exceeded 6,000,000 lb. It was, however, still a minor industry for the exports in 1869, which were valued at £132,032, accounted for only ten per cent. of the total exports. The exports of sugar, molasses, and rum, on the other hand, represented a value of £978,366, or 77 per cent. of the total exports. The area under cacao, in 1868, was recorded as 16,020 acres, of which four-fifths was located along the Northern Range, principally in the Ward Unions of Arima, Tacarigua and St. Ann (11). The estates were so scattered, and the density of the labouring population was so small, that the planters were seldom able to comply with the regulations of the Immigration Ordinance, which required the maintenance of estate hospitals, and the regular visits of registered medical practitioners (27). Consequently few cacao planters were able to obtain indentured immigrants. As the sugar estates relied more and more upon East Indian labour, West Indians became available for the cacao estates, and they enabled the industry to maintain a steady expansion. In 1869, however, there occurred an unprecedented drought which resulted in diminished yields during the next five years. Prices, too, were falling and averaged only $8.25 a fanega in 1874, the lowest recorded for many years (28). Thus, the period closed with bright prospects for the sugar industry, but with an uncertain outlook for the cacao industry.

Table IV.

Average Annual Exports of Trinidad.

Sugar and Cacao from 1800-09 to 1860-69.

Period.	Sugar Hogsheads.*	Cacao. lb.
1800-09	14,000	447,000
1810-19	15,000	1,113,000
1820-29	24,000	2,457,000
1830-39	23,000	2,525,000
1840-49	26,000	3,358,000
1850-59	31,000	4,675,000
1860-69	40,000	6,364,000

* The weight of the hogshead varied. De Verteuil gives it as 1,600 lb.

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REVIEWS.

The Projection of England.

By S. G. Tallents. Pages 48. *Faber & Faber, Ltd.*, London. *Price* 1s.

In this little pamphlet Sir Stephen Tallents puts forward a plea for the deliberate study of what is stated to be a new art—the art of national projection. Coming from one who has occupied with efficiency the position of Secretary of the Empire Marketing Board since its inception, the idea is obviously worthy of careful consideration. It is pointed out that England has always held herself aloof from the world's opinion but under changed conditions she can no longer afford to do so. Her responsibilities demand that she should "project" a true picture of her qualities on the screen of the world's mind. Her achievements in all matters of industry, in the realms of science and art and in such things as communications, are stressed and also the necessity for drawing attention to the beauties of English countryside and the individual qualities of English life and culture. Every individual citizen has a part to play in the development of this new art. The foundation of a School of National Projection is visualised which shall be outside politics. A perusal of this thoughtful little work is recommended.

G. E.

Sugar Abstracts.

Vol. I, 1931. *Palmer Publishing Corp. of New York*, United States of America. $5.

This book is the first year's abstracts of the I.S.S.C.T., published monthly in *Facts about Sugar*, bound into a single volume. An index of the subject matter is provided under seven headings, viz.: Beet Sugar Technology, Cane Sugar Technology, Sugar Beet Agriculture, Sugar Cane Agriculture, Books, Patents, and General. There is also an alphabetical index of authors. The book fills a long felt want in the sugar industry, in that now technologists have an authentic abstract of each and every paper that is published. It is suggested that the utility of the index could be very much increased if the subject matter part was not only arranged alphabetically (as at present) but also according to the various subjects. An enormous amount of work is no doubt expended in compiling these abstracts, and it is felt, therefore, that every available benefit should be obtained from their collection. In respect to this, the provision for obtaining information rapidly is an extremely important matter.

The binding of the book is strong and serviceable but not neat, and two different colours of paper are used for no apparent reason. The text is clear and the figures, although small, are well produced.

J. G. D.

PITTING DISEASE OF BANANAS.

Its Nature and Control.

By C. W. Wardlaw and L. P. McGuire.
Low Temperature Station.

1. Introduction.

[*Pitting or Spotting disease of the cushions and finger-stalks constitutes one of the principal sources of wastage in Brazilian banana cargoes. The following is a brief account of our investigation of this important problem during our recent scientific visit to Brazil.*]

Pitting disease is now recognised as one of the principal sources of wastage in Brazilian bananas. So far as current information goes, it appears to be equally prevalent on the several farms from which fruit is reaped for export.

Pitting disease, or spotting, developed during overseas transport has already been the subject of investigations in England. From typical pits or spots Tomkins (1) isolated a species of *Pestalozzia* on a large number of occasions, but was unable to reproduce the disease in inoculation experiments. From spots which had become enlarged during ripening, species of *Gloeosporium* and *Fusarium* were isolated but, though capable of exploiting banana tissue, these were obviously secondary to the original parasite. Tomkins came to the conclusion that it could not be said from examination of bunches in England, how or when spotting originated, but suggested that it was probably of plantation origin, and that its incidence was to some extent influenced by the position of the large flower bract; the need for fuller investigation in the field was also indicated.

The following is an account of our re-investigation of this important source of wastage.

2. Occurrence.

The development of pitting was followed in detail on the Cavendish, Giant Fig and Silk varieties during storage trials conducted in Santos (17 days at 53°F.; ripening room, 68°F.). Prior to storage at 53°F., all fruit was carefully inspected, the finger-stalks and cushions of the upper two hands receiving a particularly close scrutiny. Without exception, there was no sign of infection which could be regarded as the initiation of pitting disease.

On removal of bunches to the ripening room, a second inspection showed that typical pitting had developed during the period in cold storage. This was present chiefly on the cushions and finger-stalks of the two top-hands and sometimes on some of the finger-stalks of the third and fourth hands. In addition, it was noted that a pitting of similar origin was present in a localised manner down one side of the main-stalk, and again, in some bunches there was a similar localised collection of spots or pits towards the distal ends of the fingers.

3. Isolation of the Causal Organism.

Typical specimens of pitting on main-stalks, cushions, finger-stalks and finger-tips were collected for mycological investigation. The epidermis was stripped off and small pieces of diseased tissue were picked up on a sterile scalpel from the innermost region of the pits and planted on a suitable sterilised culture medium.

In the majority of cases, a slow-growing white fungus was obtained. When grown on sterilised green banana skin, it had a pale greyish colour and produced spores in considerable numbers. It has been identified as *Piricularia grisea* (Cke.) Sacc., and since it has repeatedly been isolated in pure culture from spots in their earliest stage of development, before secondary fungi had entered the wound, it may safely be accepted as the causative agent in the production of pitting disease. The other fungi isolated were species of *Fusarium*, and although these grow more rapidly than *Piricularia grisea* they were definitely in the minority.

After a few days in the ripening room, the services of an independent witness were enlisted to collect 10 samples of pitting and a second collection was made by us. In all of these a delicate greyish fungus could be discerned on the surface of each infection. When scraped off and examined microscopically, sporulation was found to be abundant, and *Piricularia grisea* was again identified on each specimen. In some, however, the advent of fast-growing, secondary fungi had already taken place, the spores of *Fusarium sp.* and *Gloeosporium musarum* being identified. With the progress of the disease in the ripening room, the original pits tended to become extended and overgrown by secondary fungi. As *Piricularia grisea* is a slow growing organism, it is easy to understand how it may be overlooked or suppressed if cultural work is carried out on any but the earliest stages of infection.

4. Nature of Infections.

Most of the common pathogens of bananas in storage tend to cause spreading blemishes on the skin, sometimes more or less superficial, or a more generalised soft rotting may be p oduced. In the case of pitting disease in its primary stage, the infections remain curiously localised. Although the spots are of small diameter, a deep invasion of the underlying tissue is the rule. For this reason, the advent of secondary fungi in the case of finger-stalk infections soon leads to finger-dropping. Again, even comparatively small spots (1.0-1.5 cm. diameter) on the main-stalk are often seen to be considerably shrunken and fissured on account of the deep invasion and rotting effected in the underlying tissue. This active penetration while fruit is still in the green, cold storage stage, produces an effect similar to wounding and so prepares the way for weaker parasites when greater maturity is reached, a consideration which undoubtedly places pitting disease among the principal sources of wastage in cargoes.

5. Notes on Piricularia grisea.

This fungus is chiefly known to pathologists as the cause of a disease of rice and other grasses, on the leaves and culms of which it produces pallid or water-soaked spots. The conidiophores emerge in clusters of two to five from the stomata; they are simple or sparingly branched, greyish, septate, and bear at their distal ends, single, ovate, two-septate conidia measuring 24-29 x 10-12 μ— a description with which the fungus repeatedly isolated by us is in complete agreement.

So far, pitting disease appears to be a feature of Brazilian cargoes only. In the very extensive Caribbean banana export industry, the fungus has not been recorded as an active source of wastage. In our own experience at the Low Temperature Station, the fungus became conspicuous on one variety and on one occasion only (2). During a long-storage trial with the College Hybrid I.C.I. (GM × B2) a large number of small spots appeared on the fingers particularly towards the distal end, while the fruit was still green. At an early stage they became brown and sunken and were surrounded by a halo of slightly discoloured tissue, while the cells within were found to be collapsed, shrunken and of a brown colour. In due course the spots spread to a diameter of one cm. or more, coalesced and became deeply sunken, the fruit being thereby rendered decidedly unsightly. When pieces of tissue from 43 spots were cultured on a sterile synthetic medium, following the usual mycological procedure, 7 gave no organism, 3 gave a strain of *Gloeosporium musarum* while 33 gave cultures of *Piricularia grisea*. While the latter was also occasionally isolated from spots on the Gros Michel, extensive pitting, such as that encountered on Brazilian fruit in storage, is negligible or completely absent in West Indian cargoes.

6. Mode of Infection.

While the disease becomes manifest during the period in cold storage, there can be little doubt that the infections are originally of plantation origin. The pecular localised distribution of pits on the exposed uppermost parts of the bunch, has been the subject of much comment.

In the present re-investigation, it seemed of first importance to determine the factors responsible for this characteristic distribution of infections, so that adequate preventive measures might be prescribed. In the first place, the position of the pits is very strongly suggestive of a downward percolation of spore-laden water from the foliage leaves above, since the confluence of the latter at the crown of the plant constitutes a kind of funnel which would undoubtedly direct rain-water on to the uppermost part of the bunch. Two possibilities were investigated in some detail:—

(1) That *Piricularia grisea* might be the cause of some of the typical leaf infections, from which spores, in wet weather, would be transferred to the bunch in the manner suggested.

(2) That the broad foliage leaves might serve as a collecting ground for wind-blown spores which would ultimately be washed down on to the bunch.

In point of fact neither of the two possibilities was realised. In the first place, while some pitting develops on most bunches, leaf-spotting is by no means prevalent throughout the plantations. A considerable collection of typical leaf spots was made but in no case was *Piricularia grisea* found in association, the principal pathogen being *Scolecotrichum musae*. Again, when a number of scrapings of leaf surfaces were examined at length, although numerous spores of common sapropyhtes were present, the typical pear-shaped spores of *Piricularia* were not observed. It is, of course, by no means impossible that some spores of this fungus might be found if a sufficiently prolonged examination could be made, since even a healthy banana leaf normally carries a large number of wind-blown spores of different organisms. In the circumstances, however, in view of the multiplicity of pit infections, we were led to conclude that leaf surfaces as a collecting ground could be ruled out.

Having eliminated the foliage leaves, our attention was next directed to the "transition" leaves and bracts as possible sources of infection. The "transition" leaf, sometimes known as the "protecting leaf" is the last of the series of green vegetative leaves. It immediately overhangs the bunch and differs considerably from the normal foliage leaves, being intermediate in character between the latter and the bracts which protect the young hands of fruit. It tends to be very much reduced in length, the blade is insignificant and the petiole has a flat sheath-like structure, which clasps the inflorescence axis at the point of emergence from the trunk. This sheath is usually of a soft succulent texture and tends to hang down over the bunch. Usually it is short-lived and soon becomes attacked by various fungal organisms.

A collection of "transition" leaves and top-hand bracts in the earlier stages of decay was made. These were placed in moist chambers for a few days to permit of spore formation. A systematic microscopic examination was then made, and the presence of abundant infections of *Piricularia grisea* was demonstrated beyond doubt. These commence as round, water-soaked spots, but, as the leaf or bract ages, the infections spread rapidly, causing a brownish, moist region of decay on the surface of which numerous spores are formed. In short, *Piricularia* is present as a primary parasite on the "transition" leaves and bracts, while the position of the latter is obviously such as to account for the localisation of infections which is characteristic of this disease.

Attack by *Piricularia grisea* is quickly followed by other fungi, among which *Gloeosporium musarum* and *Fusarium sp.* were much in evidence, and, of course, "transition" leaves and bracts in the normal course of decline may become affected by such fungi in the absence of *Piricularia*. Here it may be mentioned that fruit infections caused by

Gloeosporium musarum, though they may be generally distributed over the fruit surface, are most frequently found on the cushions and finger-stalks of the uppermost hands. From the evidence submitted this localisation of infections is also referable to the fungi present on transition leaves and bracts and to the downward percolation of spore-laden water from them. It follows that preventive measures designed to eliminate pitting will, at the same time, effect a very considerable diminution in the amount of disease caused by *Gloeosporium musarum*—one of the principal storage pathogens on the banana.

Once transition leaves and bracts become diseased, the transference of spores to the bunch may take place during the first shower of rain. The precise time at which the actual infection of finger-stalks and cushions occurs has not yet been ascertained and will be the subject of further investigation in due course. What in definitely known is that the infections of both *Piricularia grisea* and *Gloeosporium musarum* remain latent or dormant until fruit is reaped and placed in storage.

7. Remedial Measures.

Considered in the light of the data set out above, remedial measures obviously depend on the removal of " transition " leaves and bracts before they become subject to infection by fungi whose spores, during moist weather, will drip on to the uppermost hands of the bunch. The requisite treatment is not only simple and very inexpensive, but, in addition, a consideration of the rate of infection of leaves and bracts indicates that ample time is available for the necessary inspection and treatment. The following procedure is suggested :—

1. Weekly or fortnightly inspection, according to weather conditions and the number of new bunches being shot, should be carried out by a labour gang under careful supervision.

2. The transition leaves should be cut off at the crown of the plant with a small sharp knife. Removal by tearing may prove injurious to the main-stalk.

3. The bracts which protect the hands should be carefully removed. Normally these soon become detached and either fall to the ground or remain in a decayed condition among the fingers. If the bracts, during the first inspection, cannot readily be detached by a gentle pull, they should not be torn off, but left for removal at the next inspection.

4. Should the position of the bunch render it liable to sun-scorch, an over-hanging leaf should be bent down to afford the necessary protection.

REFERENCES.

(1) Tomkins, R. G., Wastage in Banana Transport. *Tropical Agriculture*, VIII, No. 10, 1931, pp. 255-264,

(2) Wardlaw, C. W. and Mc Guire, L. P., Transport and Storage of Bananas with special reference to Chilling, *E.M.B.* Report No. 45, 1931.

CULTIVATION OF SISAL.

SISAL (*Agave sisalana*) is a fibre-yielding plant of great and increasing importance in East Africa, and some account of the problems in connection with its cultivation are given by F. J. Nutman of the Amani Research Station (*Bulletin of the Imperial Institute*, Vol. XXIX, p. 299). Up to the present, scarcely any research has been carried out with this crop, as it has been possible to grow it profitably with a minimum of scientific knowledge, and since the plant is not an annual, field experiments are necessarily long and expensive. One of the most important physiological questions is a proper understanding of the factors influencing flowering, for after the production of the inflorescence the plant dies and no more leaves, the source of the fibre, are developed. The suggestion that flowering, or ' poling ' as it is termed, occurs after the formation of a given number of leaves is rejected, but it is still uncertain whether, and in what way, soil, climate, and water relations can be correlated with this fundamental change in the plant's development. Fruiting, on the other hand, appears to be influenced by quite different factors, for although flowering is a universal phenomenon, fruit formation is confined to the highlands of Kenya. Propagation is in consequence entirely vegetative by means of bulbils and suckers, and further investigations are needed to determine if treatment of the parent can influence the after behaviour of the suckers. Other important problems arise in connection with the drought-resisting properties exhibited by sisal, for there is a tendency to extend its culture into the more arid parts of East Africa, and under semi-desert conditions special cultivation operations appear to be necessary. In addition to physiological problems such as these, questions of agronomy and genetical interest abound, and if the sisal industry is to survive the critical period through which it is at present passing, further research is of fundamental importance.—(*Nature*, Vol. CXXIX, No. 3245, page 62.)

ERRATUM.

Manurial Experiments with Sugar Cane.

On page 155, Vol. IX, No. 5, second column, paragraph VI, Summary, line 4, *tons* should read *cwts.*

WANTED TO PURCHASE.

The Editor of *Tropical Agriculture* would be glad to hear from any reader wishing to dispose of :

(*a*) Vols. I, II, II, of the *Bulletin of Miscellaneous Information*, edited by the late J. H. Hart, Superintendent of the Botanic Gardens, Trinidad.

(*b*) Vols. V, VI, VII, of the *Agricultural Record*, Official Journal of the Central Agriculural Board of Trinidad.

TREND OF THE MARKETS.

[*The notes below are based principally upon running charts of the prices of the basic grades and upon general statistical information gleaned from contemporary publications and cablegrams and are intended to be a record of movements. An attempt is made, where possible, to indicate the market outlook at the time of going to press, but no responsibility for the accuracy and subsequent truth of such observations is assumed. Unless otherwise stated the prices quoted are spot, London.*]

SUGAR.—Prices on the Home Market have ranged as follows (c.i.f. per cwt.) :—

	Foreign.	*Preferential.*
	s. d.	*s. d.*
31st March ..	5 1½	8 10½
7th April ..	4 3¾	8 1½
14th April ..	4 4½	8 1½
21st April ..	4 5¾	9 1½
28th April ..	4 6	9 3
5th May ..	4 3¾	9 0
7th May (1931)	6 0	9 9

There were three outstanding features during the past month: the announcement that agreement had at last been reached amongst countries participating in the International Convention; the Budget statement and Licht's first estimates of the sowings in Europe which show heavy reductions in the most important countries. The Cuban crop was fixed by the Convention at about 2,700,000 tons while Europe and Peru guaranteed to reduce their total export quota by the amount which Java's exports during April to March 1932/33, exceed 1½ million tons (metric). The Budget provided for increased preferences on British Colonial Sugars imported into the United Kingdom, and reductions in the rates of Excise Duty payable on Home-grown Beet Sugar. Colonial Preference has been increased by one shilling per cwt. basis 96 per cent. polarization while a supplementary preference of one shilling on the same basis is to be granted on a limited quantity (275,000 tons) shipped to the United Kingdom during the year ending 30th April, 1933. Both preferences are, however, subject to adjustment according to the level of prices of foreign full-duty Sugars ruling in the open market. Of the 275,000 tons, British Guiana has been allocated 46,900 tons, Trinidad, 31,900 tons, Barbados, 25,400 tons, Jamaica 19,400 tons and the remaining West Indian islands 15,600 tons. Prices on the whole have been disappointing and new low records have been established. The present unsatisfactory state of the market is attributed chiefly to an adverse statistical position, and lowered purchasing power.

* * *

COCOA.—Whilst stocks continue to rise in New York this has been, in a great measure, due to heavy consignments from Gold Coast and Nigeria arriving before the new regulations in the United States came into force. Therefore, stocks at primary points are down to a minimum and the market, still continues without interest of any kind. Accra cocoa is being quoted at 25*s.* c.i.f. and in Trinidad $6.70 a fanega is freely paid. —(*By courtesy of the Cocoa Planters' Association, Trinidad.*)

* * *

RUBBER.—Quotations for Plantation Sheet have ranged as follows :

	d.
30th March	1 5/16
6th April	1 5/16
13th April	1⅛
20th April	1⅛
27th April	1 5/16
4th May	2
5th May (1931)	3⅞

The price of Rubber during the past month has remained steady and Spot seems to have found its level at about 2*d.* per lb. Messrs. *Symington and Wilson* state that as this price represents rather less than half the cost of production for the average estate, it is unlikely that rubber will fall much further. There are signs already that the low price is at last having some effect by way of reducing shipments.

* * *

COTTON.—The following are the official spot prices in pence per lb. of the Liverpool Cotton Association :—

	American Mid.	*Egyptian F.G.F. Sakel.*
24th March ..	5.15	7.05
1st April ..	4.81	6.60
8th April ..	4.73	6.55
15th April ..	5.00	6.60
22nd April ..	4.95	—
29th April ..	4.82	—
6th May ..	4.53	—
8th May (1931) ..	5.39	8.30

Prices have not registered any great changes while outside factors appear mainly to have dominated the cotton situation. Sales of Sea Island were made in Montserrat at 11*d.* to 11.75*d.* and in St. Kitts at 11½*d.*

* * *

TEA.—Latest averages include Ceylon at 16.34*d.* per lb., Indian at 10.29*d.* and Java at 7.40*d.* Sales to the middle of April averaged 10.90*d.* as against 12.65*d.* last year.

* * *

COFFEE.—Jamaica has made up to 205*s.* per cwt., Costa Rica, fine first size 148*s.*, seconds, 111*s.*

* * *

COPRA.—West Indian f.m.s. is 10*s.* lower at £15 5*s.* c.i.f. London.—(*West India Committee Circular*, 14th April, 1932.)

* * *

BANANAS.—Owing to the large supplies available and the rather poor demand as a result of the cold weather, the price of Jamaicas has been reduced £1 10*s.* per ton to £15 15*s.* delivered London, and £15 10*s.* delivered nearest Railway Station; retailers pay from 6*d.* to 6½*d.* per dozen. Brazilians are slow and unchanged at £17 per ton, delivered nearest railway station.—(*West India Committee Circular*, 14th April, 1932.)